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The Clinical Anatomy of the Gastro-Intestinal Tract

BY

Thomas

T. WINGATE TODD, M.B., Ch.B.,
F.R.C.S. (Eng.),

Henry Willson Payne Professor of Anatomy in the Western Reserve University, Cleveland, Ohio; late Lecturer in Anatomy, University of Manchester.

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TO

THE BRITISH STUDENTS IN MANCHESTER

AND THE AMERICAN STUDENTS OF RESERVE,

WHOSE ENTHUSIASM

STIMULATED THE COMPILING OF THIS BOOK

PREFACE.

The contents of this volume embody the substance of the course of lectures on the alimentary canal as given in the Anatomical Laboratory of Western Reserve University. Those elementary facts which a student easily learns for himself have, in greater part, been omitted. The mouth, pharynx, tongue and salivary glands also have received no consideration in these pages. My reason for making these omissions is the necessity for condensing into small compass results of recent investigation which are of value for clinical purposes. Clinical research on the mouth and pharynx has not progressed of late years so rapidly as has investigation on the abdominal part of the alimentary tract. Hence for the presentation of a comparatively small amount of new material, it would have been necessary to add much old matter to render the account of mouth and pharynx readable and intelligible. It was therefore deemed advisable to leave out altogether the consideration of these parts.

The volume was never planned as a handbook for examination purposes. It is intended to give an outline of recent work, which has not yet found its way into anatomical text-books, to those who desire to know a little more than is required for the pass examination. It may be that in the American schools, where the outside examinership is unknown, the teacher has a freer hand than he has in Great Britain in the selection of those parts of his subject which he considers of most value for his students. Nevertheless it was the eagerness of the classes in clinical anatomy in Manchester for more advanced study and for the anatomical facts and theories

of more definitely clinical bearing which first suggested to me the advisability of gathering the material together into book form.

Inasmuch as the book is intended for the more practical side of the subject of anatomy, no attempt has been made to bring in the Basle nomenclature. Only a few carefully guarded terms are used, for the confusion introduced by that premature and ill-considered attempt to revise anatomical nomenclature is as great in America as it is in Britain.

Some misunderstanding may arise over the *lateral inguinal* line. It seems to me (see p. 3 and fig. 1) the happiest solution of the now considerable number of "vertical" lines in the neighbourhood of the old mid-Poupart line.

Illustrations have not been considered essential, as every dissecting room and atlas present a profusion of illustration. Nevertheless some have been added, especially to assist the reader to grasp the new facts brought to light by radiography. For practically all of these radiograms I am indebted to Dr. A. E. Barclay of Manchester, in whose laboratory I gathered the information so valuable to clinician and anatomist alike.

In drawing together the material into book form I had help from both my British and my American colleagues, many of whom I have not space to mention by name. But to my chief, Professor Elliot Smith of Manchester, to Professor Lorrain Smith of Edinburgh, and to Professor Keith of London, I stand greatly indebted. In England, Professor J. W. Smith, Messrs. Stopford, Morley, Hughes, F. Craven Moore and Barclay, and in America, Drs. Hamann, Macleod, Ingalls, Black and F. C. Herrick have been unsparing in their help. To

all of these gentlemen I desire to express my sincere thanks. Prosector Leonhart of this department has also put me under obligation for much assistance in the preparation of dissections necessary to the work.

Although from considerations of space much has had to be passed by, it is but fair to state that without the untiring zeal of Mr. J. C. Miller, the departmental librarian, the material now brought together could not have been gathered. To Miss A. Parker, the stenographer, also I wish to acknowledge my thanks for the patience and care she has at all times bestowed on a very tiresome manuscript.

I am also indebted to Dr. Stopford and Mr. H. M. McKechnie, Secretary of the Manchester University Press, for help given in passing the book through the press.

T. WINGATE TODD.

CLEVELAND, OHIO,
19th March, 1915.

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CHAPTER I.

The Abdominal Wall and Diaphragm.

Since the wall of the abdomen is differentiated from that of the thorax by the attached margin of the diaphragm to the costal arches, portions of the seventh to the tenth and the whole of the eleventh and twelfth ribs lie in the wall of the abdomen. In respiration the last two ribs are prevented from vertical movement by their muscular attachments and simply tilt their ventral extremities outward to accommodate the descent of the bulky subphrenic organs in inspiration (176).

The term anterior or ventral abdominal wall is usually restricted to the rhomboidal area between the costal margins above and the inguinal (Poupart's) ligaments below.

The lateral abdominal wall consists largely of the costal arches, but between the costal margin and the iliac crest is a small unprotected area, the flank, an incision into which is properly termed laparotomy. The use of this word has been extended to cover an incision through the ventral abdominal wall into the peritoneal cavity, which incision is correctly known as a cœliotomy.

The infrasternal fossa lies in the angle between the two costal margins. The size of this angle varies with the size of the chest and the stage of respiration. It is greater in men than in women, and is very narrow in cases of pigeon chest. Its apex lies approximately in the plane of the disc between the ninth and tenth dorsal vertebræ. With inspiration the costal margins separate and increase the infrasternal angle. This is the result

of the action of the intercostal, scalene, trapezius and sternomastoid muscles; in other words, of the respiratory musculature of the thoracic cone. The diaphragm which on contraction tends to lessen the infracostal angle is acting normally at a disadvantage and is thus overcome by its antagonists. Should, however, the spinal cord be injured below the origin of the phrenic nerves, the infracostal angle becomes less in inspiration through the unhampered action of the diaphragm. If one side of the diaphragm is paralysed or pushed upward, the corresponding costal margin flares more on inspiration than the healthy one. Should the diaphragm be in spasm or be pushed downward on one side and the healthy muscle acting to greater advantage, it will cause the corresponding costal margin to fall in toward the middle line during inspiration, while the other costal margin may be making its normal outward movement (155).

The umbilicus varies in prominence and in position with age, sex and attitude. It is prominent and relatively low in the infant, the latter fact probably resulting from the large liver and small pelvis which together cause the abdominal organs to bulge the ventral wall especially above the umbilicus. In the adult the umbilicus lies approximately at the junction of the middle and lower thirds of a line joining the suprasternal fossa with the symphysis pubis (165). The umbilicus is elevated by an intra-abdominal tumour rising from the pelvis; it is lowered by a tumour in the upper abdomen. In the erect posture the umbilicus lies at a slightly lower level than in the recumbent attitude. In the latter position the umbilicus approximates the plane of the disc between the third and fourth lumbar vertebræ. It is usually about 3 cm. above the iliac crests.

The most prominent point of the iliac crest is marked by a tubercle 6 or 7 cm. distant from the anterior superior spine. The crest between the spine and tubercle, together with the posterior superior spine and the crest adjacent to it, is subcutaneous. Between these areas fatty subcutaneous tissue covers the crest so that the iliac crease lies horizontally below the crest itself. In stout subjects the tubercles also may be covered, thus reducing still further the subcutaneous extent of the crest. The dimples over the posterior superior iliac spines are well marked in both male and female. They indicate the level of the second sacral spine. In the male there is also a second depression above the dorsal part of the iliac crest, over the space known as Petit's triangle, between the borders of the latissimus dorsi and external oblique muscles. The depression is known as the lateral superior lumbar fossa (282). It extends somewhat over the two muscles just mentioned. But in the female it is obliterated by the fatty pad of the flank.

The pubic spine approaches the horizontal plane in which lies the upper end of the great trochanter. It is distinct in thin males, but in females and in stout males it is hidden by subcutaneous fatty tissue. In men it can be found by invaginating the scrotum, and in women by following the tendon of the adductor longus to its origin just beneath the spine.

Of arbitrary subdivisions in the abdominal wall the following are of most frequent use.

The lateral inguinal, or Poupart, line, which replaces the old mammary and mid-Poupart lines, meets the inguinal ligament midway between the anterior superior spine and the symphysis pubis, and reaches the clavicle midway along its length (or midway between the supra-

sternal fossa and the outer border of the acromion). Though often termed vertical, this line may be inclined obliquely, the exact slope being determined by the relative breadth of hips and shoulders.

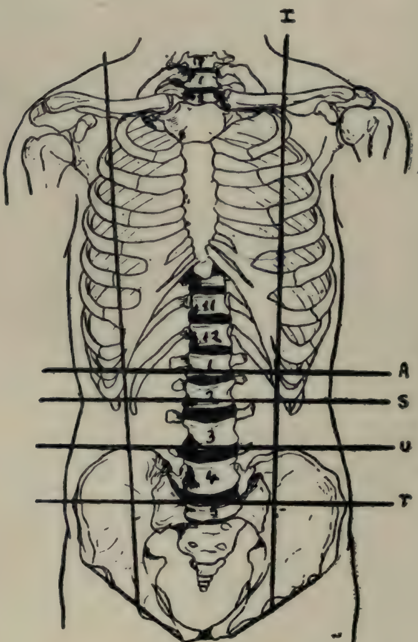

Fig. 1. Guiding lines for topography of the abdomen.

This figure, which is used throughout the volume as the basis on which to plot the organs, itself represents the typical asymmetry of the body.[1]

A, Addison's transpyloric plane; S, subcostal plane; U, umbilical plane; T, intertubercular plane; I, lateral inguinal line.

1. The left clavicle is quarter of an inch longer than the right, and the left shoulder higher than the right. A slight Harrison's sulcus at the level of the fifth rib on the left side is shown. The obliquity of the sternum and slight scoliosis associated with asymmetry of sacrum and pelvis generally are quite commonly seen. The lateral inguinal lines

Three horizontal planes, known respectively as the inter-tubercular, the infracostal (or subcostal) and trans-pyloric planes, are also used.

The inter-tubercular plane is indicated by a line drawn round the body touching the tubercles which mark the most prominent point of the iliac crests. The plane passes through the spine of the fourth lumbar vertebra and through or close to the disc between the fourth and fifth lumbar vertebræ.

The infracostal plane passes through the lowest point of the costal margin (*i.e.*, tenth costal cartilage) and in or close to the disc between the second and third lumbar vertebræ.

The transpyloric plane of Addison is that which passes through the body midway between the apex of the infra-sternal fossa and the umbilicus, a point equally well

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have not the same slope and do not cross the costal margin at precisely the same level on both sides. Several apparent inaccuracies are explained by the fact that one cannot represent three dimensions in one plane. The foreshortening at upper and lower ends of the drawing is indicated by the short vertical length of the manubrium and by the amount of the cavity of the true pelvis exposed to view. Addison's transpyloric plane is indicated at the site at which it actually did occur, but since the ventral convexity of the thoracic and abdominal walls cannot be represented in the drawing, the plane appears to lie at a lower level than it should when direct measurement is made of the actual illustration. The tubercles of the iliac crests do not indicate the summits of the crests; nevertheless they are not so far below the level of the summit as appears to be the case in the drawing. This apparent error is necessary for the perspective. As a result the intertubercular and umbilical planes appear at a lower level than they should, relative to the iliac crests. As a matter of fact the highest points of the crests in this individual are represented by the prominence so plainly shown on the left crest dorsal to the tubercle. Radiographers state that the umbilicus lies at or a little above the highest point of the crests; hence the drawing is in reality accurate, for according to the plane in which the Röntgen rays strike the pelvis, the apparent level of the crests will vary somewhat. The several horizontal planes do not invariably strike intervertebral discs, but it will be recognised that the practical levels of the planes given in the text are purely working approximations.

indicated by the midpoint between the suprasternal fossa and the pubic symphysis. It indicates approximately the level of the disc between the first and second lumbar vertebræ, and cuts the costal margin at the same point as does the lateral inguinal line, that is to say, on the ninth costal cartilage. In the horizontally-placed cadaver the pylorus lies in this plane. As the pylorus is not a fixed point, but varies with posture, age, sex, distension of the stomach, and other conditions, the plane does not invariably mark its site in the living (see p. 80).

The skin of the ventral abdominal wall is thin and delicate and of much finer texture and possesses much smaller sebaceous glands than that of the back. In young men the skin can easily be pinched up and moved on the deeper fasciæ and muscles, owing to the small quantity of subcutaneous fat. In young women the fat is more abundant and forms a pad around and below the umbilicus, thus giving rise to a more rounded appearance of the abdominal wall. The fat below the umbilicus increases in amount with age, especially in women who have passed the climacteric and in younger women who have borne children. This subcutaneous fat sometimes reaches a thickness of six inches, and its weight, together with an associated lack of muscular tone, causes the abdominal wall to sag downward.

The fold of the groin is dependent for its existence upon the presence of subcutaneous fat in the abdominal wall and thigh. In infants the fat of the abdominal wall extends downward over the thigh, thus determining a lower level for the inguinal crease. It is this fact which makes the incision for inguinal hernia in babies appear relatively high in the abdominal wall.

In infants there is a transverse crease convex below,

which passes across the abdominal wall between the umbilicus and the pubis. This gives a better indication of the site of the inguinal canal than does the so-called inguinal crease itself.

In adults of both sexes a transverse crease above the umbilicus is produced by leaning forward when sitting.

Atrophy of the skin from tension results in the production, especially below the umbilicus, of lineæ albicantes or atrophicæ in pregnancy and ascites. The scars may be pigmented. Incision through the abdominal wall in the median line is frequently followed by a pigmented scar.

Bulging of the abdominal wall is produced in the infant by the large size of the liver and by the distended intestines, which usually contain a large amount of gas from the swallowing of saliva. In young females bulging is frequently caused by intestinal distension, in older females by subcutaneous fat. In male adults bulging is usually produced by the accumulation of fat in the mesentery and omentum.

Retraction of the entire abdominal wall occurs in emaciation and in hysteria. In gastroptosis the wall above the umbilicus is scaphoid; that below is convex.

The recti muscles form well defined columns one on each side of the middle line. Below the umbilicus only a very small interval exists between them. Above the umbilicus the interval is greater. Each is enclosed in a sheath formed from the lateral musculature of the abdominal wall. Between the recti the fasciæ blend to form the linea alba, which is broader above than below the umbilicus and is represented on the surface, in its upper part at least, by a median groove. It may be covered by fat below the umbilicus or in its whole extent.

The skin overlying it below the umbilicus may be pigmented to form the linea fusca. The outer margin of the rectus forms the linea semilunaris, which reaches the costal margin at the intersection of the lateral inguinal and transpyloric lines, a site where the wall is occasionally weak and may bulge on coughing. Below the umbilicus the linea semilunaris is often obscured by subcutaneous fat. At its tendinous intersections the rectus is adherent to the ventral wall of its sheath. Persistent contraction of one of the muscular subdivisions of the rectus may occur in visceral disease (*e.g.*, appendicitis) or may cause the phantom tumour sometimes noted in hysteria. By giving tone to the ventral abdominal wall, the recti fix the lower part of the chest in breathing. Hence a man breathes mainly with the lower chest when standing erect, but with the entire chest when recumbent, the tonic action of the recti being no longer necessary in the latter position.

Lateral to the rectus is the mass of the musculature comprising the obliques and transversus, which forms a prominence on the lateral abdominal wall, in the upper portion of which digitations of the external oblique may be visible. The prominence fades away below about the level of the anterior iliac spine.

In rickets the fibrous tissue comprising the lineæ alba et semilunares may become relaxed and bulge to form the trifoliate abdomen. A similar condition occurs in the atonic abdominal wall after repeated pregnancies, though in the latter case the weakness is manifested mainly in the linea alba.

The fibrous tissue of the abdominal wall especially that of the linea alba is sometimes the site of a recurring fibrous tissue growth called a desmoid tumour.

At the time we are discussing the abdominal musculature, certain facts may be mentioned relative to the diaphragm.

Keith (177) gives the following description of the position of the diaphragm. The xiphisternal line drawn round the trunk at the junction of the body of the sternum with the ensiform cartilage (xiphisternum) cuts the lateral inguinal line on the fifth costal arch. If a strip of tinfoil be placed round the body at this level and the patient examined radiographically, the diaphragm is seen to present a definite relation to the foil, thus:—

Patient upright.
Right lateral inguinal line—dome in xiphisternal plane.
Midsternal line—central tendon 10 mm. below xiphisternal plane.
Left lateral inguinal line—dome 5-10 mm. below xiphisternal plane.

When the patient is laid horizontally the domes rise about 10 mm. above the points mentioned.

In the thoracic type of respiration the movement of the diaphragm is 10 mm. above the xiphisternal plane in expiration and 25 mm. below it in inspiration. In the abdominal type the corresponding figures are 25 mm. above and 65 mm. below the plane. For practical purposes the right dome may be indicated on the lateral inguinal line in the fourth intercostal space and the left on the corresponding line in the fifth space. If the position of the dome is 25 mm. or more below the normal, the diaphragm may be considered to participate in a condition of visceroptosis.

The lower six dorsal nerves, which also supply the

abdominal alimentary canal, send branches to innervate the abdominal wall. The seventh nerve reaches the middle line at the infracostal triangle, and the tenth at the umbilicus. The twelfth nerve reaches the middle line just above the symphysis pubis. The general direction of the nerves must be considered in all abdominal incisions. It is to avoid wounding the nerves that the kidney incision is made parallel to the last rib downward and forward from the lateral edge of the erector spinæ. Failure to observe this rule results in atrophy of the musculature with consequent lumbar hernia. The general direction of the nerves is indicated by "girdle pains," in the distribution of herpes zoster, and in the band of atrophic ichthyotic skin which results from the paralysis of intercostal nerves in some cases of tuberculous spine.

As these nerves all pass into the rectus sheath, vertical incisions in the linea semilunaris are followed by paresis and mistrust by the patient of the corresponding rectus, and sometimes by a ventral hernia. For such a procedure is therefore substituted, when possible, an incision through the two walls of the rectus sheath, the muscle with its nerves being displaced outward.

Kammerer's vertical incision for appendicitis at the outer border of the rectus may result in damage to the eleventh and twelfth dorsal nerves and to the iliohypogastric branch of the first lumbar nerve.

It has been stated that Chevassu's incision for malignant testicle and lymphatic nodes is not followed by an abdominal hernia. It would be instructive, however, to learn of such patients a considerable time after the operation, supposing them to be still alive, for such a statement is not credible without further evidence.

A right inguinal hernia sometimes follows the ordinary Bassini incision for appendicitis, but is more likely to develop if the presence of abscess has required drainage. The hernia results from paralysis of the musculature following the involvement of the first lumbar nerve. Happily for the patient this nerve, together with the last dorsal, is usually double, so that even if a trunk is divided all the fibres of the nerve are not severed. The ilio-inguinal branch of the first lumbar nerve is frequently laid bare in the Bassini operation, and if involved in the scar gives rise to neuralgic pain or cutaneous hyper-sensitiveness, and is hence removed on sight by some surgeons (151).

The fact that each nerve which distributes branches to the abdominal wall, also supplies twigs to the alimentary canal accounts for the hyperæsthesia and local contraction found in a part of the abdominal wall in disease of the canal. It accounts also for the alimentary reflex—the relaxation of the abdominal wall associated with distension of the alimentary canal. This is the reason for the tightness of one's clothes after a heavy meal. Owing to this reflex a dog can and often does double its abdominal contents at a meal without inconvenience. That the arc is completed in the alimentary mucosa and not in the peritoneum is shown by the fact that the reflex is not called forth by injection of air or saline solution into the peritoneal cavity (187).

With the exception of the deep epigastric vessel below and the superior epigastric above in the rectus sheath, behind the muscle, the arteries of the abdominal wall are not clinically important.

The veins present one of the series of anastomoses between portal and systemic circulations, which become

important in portal obstruction. The veins around the umbilicus have small anastomosing channels along the ligamentum teres with the portal system in the hilum of the liver. In portal obstruction portal blood passes in the reverse direction through these veins and to the abdominal wall and thence through anastomosing channels to veins in the axillæ and groins. Frequently there exists a large vein which joins the axillary and inguinal areas along the flank. The umbilical veins in very rare cases form a large mass known as the caput medusæ. In the Talma-Morison operation for hepatic cirrhosis it is unlikely that good results are due simply to venous anastomosis.

The lymphatic vessels of the abdominal wall pass to nodes in the axillæ and groins, the vessels of the several areas anastomosing across the middle line and the umbilical plane.

Certain developmental anomalies should receive notice in passing. These are hernia, umbilical fistula and ectopia vesicæ.

Of the herniæ, the inguinal and femoral varieties will be considered separately. The others, such as obturator, sciatic and diaphragmatic types, are rare, and as a rule are not diagnosed until the abdomen is opened. The diaphragmatic form may also be acquired. Hamant and Thiébaut divide them into two groups, those without a sac, which pass through the foramen of Bockdaleck—the costo-lumbar hiatus, and are produced during the first or second month of fœtal life, and those with a sac, which are lodged in "diverticula" of the diaphragm, and are produced between the second and fifth months of fœtal life. In the first variety the stomach is most frequently herniated, in the second the intestine. The theory is, however, based on very little evidence (122).

The umbilicus is the scar left by the closure of the umbilical ring through which passed the umbilical veins and the hypogastric arteries, the communication of the gut with the yolk sac and the stalk of the allantois. Occasionally a remnant of the artery of the yolk sac remains, at any rate in monsters, its origin being from the abdominal aorta or the superior mesenteric artery (156). After the tying of the cord the vessels atrophy, the neck of the yolk sac having already been changed into Meckel's diverticulum and the stalk of the allantois having disappeared as a patent tube. In the case of the two last-named not having fully undergone their particular modification, a temporary urinary or fæcal fistula occurs, which as a rule soon closes spontaneously. A congenital hernia of bowel may be present, and owing to slow closure of the ring, weakly infants sometimes exhibit an umbilical hernia for a long time. In the adult, umbilical hernia occurs through the abdominal wall close to the umbilical scar and is really a form of ventral hernia. The umbilical skin is frequently drawn downwards into a pocket, which may admit three inches of a probe, and which accumulates sweat products and sebaceous secretion until a foul-smelling umbilical abscess occurs.

The linea fusca on the abdominal wall represents the line of fusion between pubis and umbilicus. According to Wood Jones (350), distension of the allantois may cause interference with its closure. Thus the umbilicus is never formed, and with the loss of the outer wall of the allantois the bladder is freely open on the abdominal wall, the condition being known as ectopia vesicæ. Associated with this condition may be one or two fistular openings of the bowel, the higher of the two being

Meckel's diverticulum, the lower a communication between the urinary system and the hind gut, which also exists in recto-vaginal, recto-vesical or recto-urethral fistula (see p. 212).

CHAPTER II.

Femoral and Inguinal Herniæ.

Between the inguinal (Poupart's) ligament with its continuation, Gimbernat's ligament, and the ilio-pectineal line on the os innominatum a space is left, which is subdivided into muscular and vascular compartments by the ilio-pectineal ligament, of which the continuation towards the pubic crest is known as Cooper's ligament (207). Through the muscular compartment pass the

Fig. 2. Right side of male pelvis showing certain aponeurotic bands. I, inguinal (Poupart's) ligament; L, lacunar (Gimbernat's) ligament; C, ligament of Cooper.

iliacus and psoas. The inner or vascular compartment gives room for the iliac vessels, of which the vein lies the more medially. Man's comparatively great pelvic breadth has resulted in the relatively considerable size

of the inner compartment with, medial to the vein, a potential passage into the thigh lodging merely areolar tissue and a lymphatic node. It is called the femoral canal; its upper opening shows usually a small invagination of peritoneum; its lower end opens into the thigh immediately beneath the saphenous opening, and the canal is of greater diameter in the female than in the male. Through the canal a femoral hernia passes to the thigh. Frequently only a small knuckle of gut is present, but a large amount of omentum or fatty subserous tissue, which makes it difficult to distinguish from a lipoma. If a larger amount of gut traverses the canal, it is supposed to pass toward the anterior superior iliac spine, being directed thither by the sharp edge of the saphenous opening and the furrow of the groin. This it does not always do, and it may indeed mount upward over the inguinal ligament to resemble closely an inguinal hernia. The sac of the hernia frequently contains muscular fibres derived from the gubernaculum.

The operative treatment is directed toward extirpating the sac and then either to closing the canal from above, as in Lotheissen's operation, in which the lower margins of the internal oblique and transversalis are sutured to Cooper's ligament (216), or obliterating the lower end of the canal. The extirpation of the sac is probably the more important part of the operation.

In the region of the femoral canal there may be an unimportant anastomosis between the deep epigastric and obturator arteries. This is dilated in some cases to form an abnormal obturator vessel. Occasionally the artery may run on the medial side of the femoral canal and is then liable to injury if the strictured neck of the

canal be opened by cutting toward Gimbernat's ligament (159). Such accidents must be rare indeed.

The inguinal canal is only slightly smaller in the female than in the male. Its direction is inward and downward. It opens into the abdomen through the internal abdominal ring which lies just lateral to the junction of the lateral inguinal line with the inguinal ligament. It opens externally at the external abdominal ring, which is a narrow obliquely placed slit, 3 cm. long and bounded by two pillars, of which the lateral is attached to the pubic spine. The canal itself is bounded below by the upper grooved surface of the inguinal ligament: its outer wall by the external oblique fascia; its inner wall by the transversalis fascia, which lines the abdomen deep to the muscle of the same name, and behind the external ring by the conjoined tendon of the two deeper muscles of the abdominal wall at its attachment to the ilio-pectineal line. The thickest parts of the conjoined tendon are its medial and lateral borders. Between these it is thin and much weaker. The weak area is bounded medially by some aponeurotic fibres of the transversalis muscle, which run from the upper aspect of the pubis to the rectus. They are called the falx aponeurotica inguinalis. Laterally the weak area is bounded by other aponeurotic fibres from the same muscle, which, encircling the internal ring on its medial side, are fused with the deeper part of the inguinal ligament. They are termed the ligamentum interfoveolare. The size of the weak area naturally depends on the extent of its two strengthened boundaries. Above, the inguinal canal ends indefinitely by the approximation of the muscular layers forming its walls. The deep wall is subdivided into three areas by the upward passage of

two arteries beneath the subperitoneal coat. These are the deep epigastric immediately medial to the internal ring, and, a little more medially, the obliterated hypogastric. Both vessels are directed toward the umbilicus the subdivision between them being often termed the triangle of Hesselbach on its peritoneal aspect.

An oblique inguinal hernia passes through the entire canal; a direct one into the canal through a weakened part of the middle or internal area of those defined above. The oblique variety is probably always associated with an imperfectly closed funicular process and is therefore potentially congenital. The funicular process is patent throughout in 30–40 per cent. of infants a few months old (178). Often this form of hernia is associated with an imperfectly descended testicle. Of cases of hernia accompanied by such imperfect descent of the testicle, 35·1 per cent. occur during the first year. Of cases of hernia without this association, only 7·7 per cent. commence during the first year (87).

Because in early life the omentum is not developed to the extent seen in the adult, its presence is rare in a hernial sac in the young. The bladder is present in 1 per cent. of hernial sacs, usually in children and on the right side. The appendix, or even the cæcum, also may be found in the sac, in which case the appendix is as liable to inflammation as in its normal situation, though inflammation in a herniated appendix is often termed strangulation. Hernia of the ovary with or without the Fallopian tube is rare, but when present it occurs as a rule in young infants and on the left side.

Interstitial hernia may occur in any of the areolar layers of the abdominal wall in the region of the inguinal canal. It probably depends upon the drawing of a

pocket of peritoneum into the space by aberrant fibres of the gubernaculum (88). Three varieties are found: (i) superficial to the external oblique, (ii) deep to the external oblique, (iii) deep to all muscles and between them and the peritoneum.

CHAPTER III.

The Peritoneal Cavity.

It is not proposed in this chapter to describe in detail the peritoneal cavity or the several mesenteries, omenta and ligaments, for all of these are discussed at sufficient length in the anatomical text-books. It is, moreover, only in its relation to the alimentary canal that the peritoneum finds a place here. Inasmuch, however, as there is a tendency to lose sight of the functional, or more correctly the clinical, subdivisions of the cavity in the mass of detailed description usually given in text-books, the subject of subdivision must be considered in this chapter.

Foremost among what may be termed the partitions of the peritoneal cavity is the transverse mesocolon. The exact attachments and the variations in position of this mesentery are given elsewhere (p. 176). At the moment it is sufficient to note that it subdivides the cavity into supra-colic and infra-colic portions, and in view of the fact that its attachment to the dorsal wall lies for the most of its extent above the plane of the transverse colon, it follows that the infra-colic portion extends upward and backward behind the supra-colic division. Subdivision into upper and lower areas is completed by the transverse colon and omentum lying in contact with the ventral abdominal wall.

The transverse mesocolon becomes greatly shortened at its extremities; indeed at the splenic and hepatic flexures and for some 5 cm. adjacent to the latter, no

mesocolon exists. Hence supra- and infra-colic compartments communicate in the neighbourhood of the flexures. The splenic flexure lying lateral to the left kidney, there is but a small communication on the left side. On the

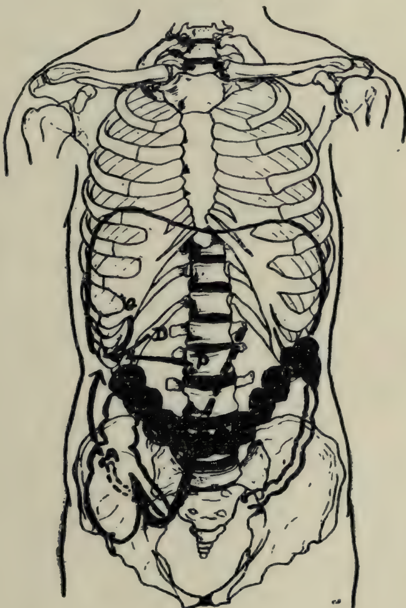


Fig. 3. Supra- and infracolic portions of the peritoneal cavity and the relation to each of the right kidney pouch (of Rutherford Morison). As the mesentery of the small intestine extends upward dorsal to the transverse colon and mesocolon, its upper part is indicated by a broken line. The arrows indicate the drainage into the pouch from gall bladder (G), appendix (A), duodenum (D), and pyloric vestibule (P).

right side, however, the hepatic flexure lies in front of the lower and medial part of the kidney, and the first 5 cm. of the transverse colon usually having no mesentery, the connection between the upper and lower portions

of the peritoneal cavity is of considerable extent. The communication occupies that part of the abdomen in front and to the right of the right kidney below the liver, and extends downward to the region of the iliac crest. Rutherford Morison has termed it the right kidney pouch and has pointed out that it is large enough in the adult to contain a pint of fluid (244). The right kidney pouch is important because, as the patient lies on his back, there is a tendency for it to become the drainage area of the appendix, gall bladder, duodenum, and even of the pyloric vestibule. It is because the duodenum and appendix each drain into this area that the diagnosis between appendicitis and acute perforation of the duodenum may be difficult, since the area of local tenderness and rigidity may be the same in both diseases.

As a rule a perforated duodenal ulcer produces peritonitis localised to the right kidney pouch. On the other hand, perforation of a gastric ulcer is more likely to be followed by general peritonitis (248), because the flow from the stomach is not so accurately localised.

When the cadaver is laid flat upon its back, a hand placed in the peritoneal cavity readily determines that the subdiaphragmatic (or subphrenic) area and the pelvic cavity, respectively, form the lowest levels of the supra- and infra-colic divisions.

The pelvic peritoneum has the least power of absorption, but the subphrenic area has a very considerable absorptive faculty. It follows, therefore, that drainage of toxic fluid into the latter must be prevented. Fowler's position, in which the patient is propped on a bed rest, is the natural result of this knowledge. The high rate of absorption is stated to be due to several causes other than the accumulation of toxic fluid through gravity.

Stomata have been said to connect the peritoneal cavity with the lymphatic vessels of the diaphragm, but this observation is discredited by Sabin (298). The piston action of the diaphragm during respiration has been stated to produce a flow of lymph toward the thorax. Certainly pleurisy following peritonitis is not uncommon, whereas peritonitis as a complication of pleurisy is exceedingly rare. Also pleurisy may follow the ascites which results from a variety of causes, and does not necessarily indicate pleural and peritoneal tuberculosis (46). Some believe that the lymphatic vessels of the diaphragm are valved in an upward direction (18).

The statement that very little absorption occurs in the pelvic cavity is illustrated by the fact that a patient with a pelvic appendicular abscess may show no symptoms of toxic origin whatever. The only signs indicating the lesion may be the diarrhœa, frequency of micturition and possible hæmaturia, all of which are but the results of local irritation. The natural tendency of all contained fluid to gravitate to the pelvis results, in certain cases of carcinoma in the upper abdominal organs, especially of the stomach, in the formation of a secondary deposit in the pouch of Douglas, palpable through the rectum (330). Implantation metastases are produced in the same manner on the ovary or uterus from carcinoma of the breast.

Both supra-colic and infra-colic areas are partially subdivided into right and left compartments by the vertebral column and the great vessels lying upon it.

In the infra-colic section this subdivision is completed by the mesentery of the small intestine, which is attached to the dorsal wall along a line running from above and to the left obliquely downward to the right iliac fossa

(see p. 141). Thus the infra-colic peritoneal cavity is subdivided into right and left lumbar areas, of which the former is directly continuous with the right kidney pouch. The latter has a small connection, alongside the splenic flexure, with the supra-colic division. It communicates over the pelvic brim with the third subdivision of the infra-colic area, namely, the cavity of the true pelvis. The infra-colic peritoneal cavity has been utilised by Cushing as a drainage area in cases of congenital hydrocephalus. He inserts a cannula through the fifth lumbar vertebra to form a communication between the spinal subarachnoid space and the peritoneal cavity.

The omentum and coils of small intestine assist in further localising an area of infection below the transverse mesocolon.

The omentum is a vascular fat-laden fold, developmentally part of the dorsal mesentery of the stomach, from the greater curvature of which it hangs down in the abdomen in front of the transverse colon, which is adherent to its deep aspect, and the coils of small intestine. It is quite rudimentary at birth, when, in common with other peritoneal folds it contains no fat. During childhood it increases in size and becomes a fat storehouse. No amount of starvation will then entirely deprive it of its adipose tissue. The omentum has important exudative and absorptive qualities, and also has the power of itself travelling to an injured or infected area, to which it becomes attached, and thus acts as a protective or localising agent. It may reach anywhere from diaphragm to pelvic floor, and is frequently found in a hernial sac, especially of the femoral variety, but usually it has more immediate relation to the infra-colic subdivision than to the supra-colic area. The omentum

pours out first serum, then leucocytes into the affected region, and glues itself to the injured gut or infected

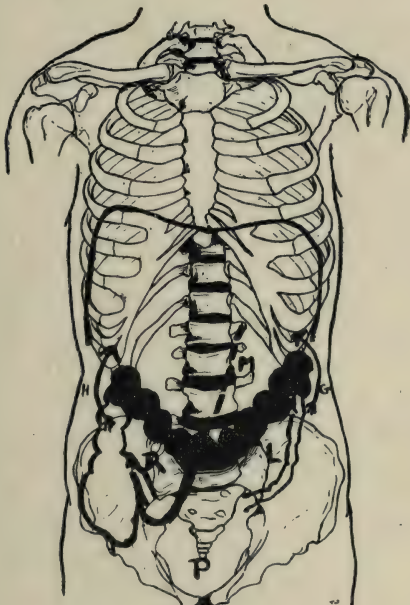


Fig. 4. Subdivision of the infracolic portion of the peritoneal cavity as found in the cadaver. The upper part of the mesenteric attachment (M) is represented by a broken line to indicate that it extends upward dorsal to the transverse colon and mesocolon, the latter of which with the omentum is not represented.

The arrow H indicates the communication between the supra- and infracolic portions of the peritoneal cavity in the region of the right kidney pouch. The arrow G shows the comparatively small communication between the two portions of the cavity on the left side.

R, right lumbar area; L, left lumbar area; P, pelvic area.

area to shut it off from the rest of the peritoneal contents. Thus the omentum adheres to the deep surface of a wound in the abdominal wall, or may act as a plug for

a hernial opening or perforated viscus. Torsion of the omentum occasionally occurs as a sequel in this protective function. In such cases the omentum is often adherent to the sac of an old standing hernia or less frequently, as in Vick's case, to an inflamed appendix (333). Absorption of fluid is not so marked a function of the omentum. For Wilkie found that in deomentised animals the rate of absorption of fluid from the peritoneal cavity is still two-thirds of the rate in normal animals (344). The omentum does, however, absorb solid particles, as Wilkie showed experimentally with charcoal. In some more obscure way the omentum is of material assistance in resisting infection. Although the cellular reaction occurs as readily in deomentised animals as in normal animals, yet the former succumb more easily to a sublethal dose of staphylococci (344). Disease of the omentum, such as tubercle or endothelioma, causes it to roll up into a mass which often lies transversely in the abdomen above the umbilicus. It may sometimes be palpated through the abdominal wall (228).

The supracolic portion of the peritoneal cavity, like the infra-colic division, is also subdivided. The vertebral column and great vessels partially separate this area into two spaces, in each of which the roof is formed by the corresponding diaphragmatic cupola. Thus, as Picqué described it, there are right and left subphrenic or hepato-phrenic and perisplenic fossæ. But the hepatic diverticulum of the lesser sac of peritoneum also lies immediately under the diaphragm, and hence Picqué speaks of this as the middle or hepato-gastro-phrenic fossa (271). A similar but more elaborate subdivision was suggested by Barnard (18). He subdivided the right subphrenic area into ventral and dorsal pouches,

the incomplete partition being the right coronary (triangular) ligament. Of these the ventral pouch is

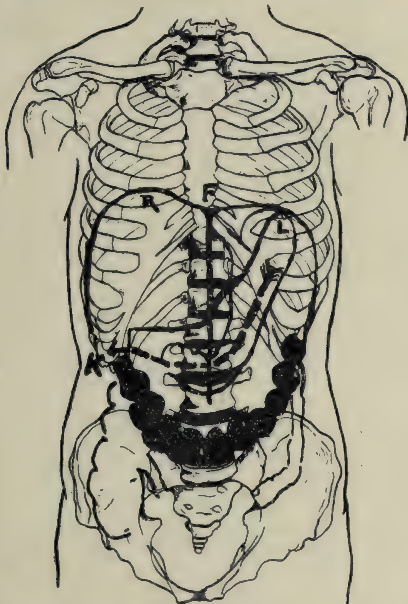


Fig. 5. Subdivisions of the supracolic portion of the peritoneal cavity. The falciform ligament (F) together with the liver subdivides the subphrenic area into right and left areas. The middle fossa of Picqué (omental bursa, lesser sac) lies behind liver and stomach, and cannot be shown. But clinically this is an area of the supra-colic peritoneal cavity isolated more completely than the others. The subhepatic channel is indicated by the long broken-lined arrow. It lies between the liver and stomach ventral to the gastro-hepatic omentum, and passes behind the falciform ligament. It is the communication between the left subphrenic area and the right kidney pouch.

R, right subphrenic (hepato-phrenic) fossa; L, left subphrenic (perisplenic) fossa; K, right kidney pouch.

separated from the left subphrenic fossa by the falciform ligament. That which Picqué calls the left fossa, Barnard termed the left ventral pouch, and he used the

designation left dorsal pouch for Picqué's middle fossa. Barnard's subdivision into ventral and dorsal pouches by the right coronary ligament is, however, incorrect, for the right coronary ligament merely acts as an incomplete partition between the renal aspect of the liver, that is, a boundary of the right kidney pouch, and the subdiaphragmatic surface of the liver, namely, a boundary of the right subphrenic area. Barnard's most important suggestion is the term subhepatic channel for the area between liver and stomach, the floor of which is directed downward and to the right to connect the left subphrenic fossa with the right kidney pouch.

The vagus, phrenic, splanchnic, intercostal, lumbar, and sacral nerves supply the peritoneum with fibres. It is useful at this point to refer to Kocher's summary of Lennander's experiments (191) regarding nerve-supply and sensations of the peritoneum. Lennander (200) made the following observations:—

(*a*) The only sensitive tissues are the peritoneal coat of the diaphragm and abdominal walls.

(*b*) The peritoneum between the sympathetic cords in front of the fourth and fifth lumbar vertebræ and over the front of the sacrum is insensitive; here there are anatomically no afferent nerves.

(*c*) The parietal peritoneum as above defined is sensitive only to pain, not to touch or temperature.

(*d*) The normal and inflamed peritoneum are equally sensitive.

(*e*) Probably the intercostal, lumbar and sacral nerves (possibly the phrenic also) conduct pain impulses, while the vagus and sympathetic do not.

(*f*) Inflammation of an abdominal organ entails pain when the parietal peritoneum is involved by the spread

of toxines and inflammatory processes along subserous lymphatics in the dorsal abdominal wall. Colic is the result of muscular action producing traction on the cerebrospinal nerves of the abdominal wall.

(*g*) Unless the parietal peritoneum is involved, there is no pain. The visceral peritoneum, mesenteries and omenta are devoid of sensation even when hyperæmic and inflamed. According to the recent experiments of Kappis, pain is keenly felt in the omenta and mesenteries (171).

(*h*) Adhesions between viscera and the parietal peritoneum produce pain by tension, but adhesions between viscera alone are devoid of pain.

(*i*) Pain is felt at a distance from the seat of disease, and results from the stimulation of the nerves of the abdominal wall by chemical, bacterial or mechanical irritation.

(*j*) Nausea and vomiting are produced when traction is made upon an abdominal organ such as the omentum, and are due to the irritation of the cerebro-spinal nerves in the abdominal wall.

Referred pain is due then to stimulation of the visceral branch, but is apparently localised in the somatic branch of a spinal nerve. Local tenderness is consequent on localised inflammation or adhesions to the parietal peritoneum. It is because they both may produce local tenderness over the right kidney pouch that appendicitis and perforated duodenal ulcer may be confused.

The peritoneal nerves take no part in the reflex which exists between the alimentary mucosa and the muscles of the abdominal wall. Injection of fluid or air into the peritoneal cavity immediately raises the intra-abdominal pressure (see p. 11).

Stimulation of a local area of parietal peritoneum results in the reflex contraction of the abdominal musculature immediately overlying. Hence one segment alone of the right rectus may be found contracted in inflammation of the gall-bladder or appendix.

It is to be observed that the lower six thoracic nerves which supply the abdominal wall and viscera supply thoracic viscera as well. Head states that the seventh, eighth and ninth dorsal segments send branches to the lungs (131), (132). Hence local tenderness or hyperæsthesia, it may be, accompanied by visceral symptoms such as vomiting, inhibition of intestinal movement and constipation, may occur at the commencement of broncho-pneumonia, phthisis, bronchitis or pleurisy. In the last-mentioned disease the tenth and eleventh nerves also may be involved. The signs may be localised to the right hypochondrium to simulate gall bladder disease, or to the left side when a perforated gastric ulcer may be suspected (18).

The blood vessels of the peritoneum, with the exception of those of the omentum, are not clinically important. Rough handling or ligature of the omentum is said to cause thrombosis of its veins which, spreading to the gastro-epiploic veins, results in venous engorgement of the stomach with consequent post-operative hæmatemesis (248).

CHAPTER IV.

Some General Features of the Gastro-Intestinal Tract.

In embryonic life the alimentary canal is subdivided into the fore-, mid- and hind-gut. The fore-gut corresponds to the canal from the pharynx to the duodenum at the point of entry of the common bile duct. The mid-gut consists of proximal and distal portions, the former of which lies above and the latter below the junction of Meckel's diverticulum with the bowel. The proximal portion becomes the small intestine between the duodenum at the site already mentioned and the entry of Meckel's diverticulum which is situated at a variable distance from the ileo-cæcal junction. The distal portion corresponds to the terminal segment of ileum with the cæcum and colon as far as the splenic flexure. The hind-gut becomes the colon from the splenic flexure onward with the rectum and anus. One or other of these embryological subdivisions may fail to develop. The portion beyond the splenic flexure may, for instance, be represented by a mere impervious cord. In ectopia vesicæ the portion distal to the entry of Meckel's diverticulum may be greatly shortened (350). On the other hand, the failure to develop may be localised to the site of junction of successive portions, resulting in constriction or occlusion. Such a condition is most frequent in the duodenum at the entrance of the common bile duct (74) and in the colon at the splenic flexure. In the subdivision just outlined the proximal part of the

duodenum falls within the same subdivision as the stomach, and it is interesting to note that surgical and radiographic aspects of the adult canal have led Mayo and Cole respectively to believe that this portion of duodenum should be considered with the stomach (66). There is also some evidence, which will be taken up in the appropriate place, that the colon should be divided functionally into proximal and distal parts which are continuous with each other at or near the splenic flexure.

In disease one of these subdivisions may be involved, the others being unaffected. Thus, as Barnard pointed out, acute uræmia attacks the fore-gut, lead-colic the small intestine, chronic uræmia the proximal or distal colon, tabetic crises the fore- or the hind-gut (20). This is by no means a complete list, nor does it indicate that even smaller portions of gut may be affected, picked out sharply by disease, but it serves to emphasise the natural subdivision of the alimentary canal.

If one scans the parts played in digestion by the subdivisions mentioned, it is obvious that the secretory function is most pronounced in the upper part of the canal, and progressively decreases in the downward direction until in the distal colon it is reduced to a minimum. On the other hand, the absorptive power increases progressively in the downward direction if one except the distal colon, in which this function also is reduced to a minimum.

The importance of the relation of absorptive to secretory areas is apparent in considering the fæcal vomiting which is due to intestinal obstruction. While it is possible that antiperistalsis may occur in the small intestine under certain conditions, such action is not necessarily called into play, nor indeed is the so-called

reversed axial current essential for the production of fæcal vomiting, the fluid of which is dark-brown and fœtid in odour, not because it contains fæcal matter, but because it is infected by the bacteria present in the bowel. As it is of a gushing character and not projectile in type, it is quite possible that it simply wells up into the mouth when the gut proximal to the site of obstruction becomes waterlogged (20). The vomiting in gall stone obstruction is also instructive in this connection. When the stone ulcerates through into the duodenum, profuse gushing vomiting occurs, since the area of canal above the site of obstruction has large secretory and but low absorptive power. During the next two or three days, that is, as the stone passes down the small intestine, the vomiting becomes less frequent and less severe, for not only does a larger area of gut come to lie proximal to the site of obstruction, thus providing a greater capacity, but the area has a progressively higher absorptive power. Indeed once the stone has passed the ileo-cæcal orifice, the vomiting usually ceases entirely.

While discussing the subject of mechanical obstruction it is well to observe the sites of anatomical constriction of the canal. Three of these are to be found in the œsophagus, namely at the commencement, at the crossing of the left bronchus, and at the termination, and three occur elsewhere in the canal, at the pylorus, at the ileo-cæcal junction, and at the anus. Of these the constriction at the commencement of the œsophagus has the least diameter. If an object without sharp angles or other special adaptations for entanglement in the mucosa, is swallowed and successfully passes this narrowed site, it will usually traverse the rest of the tract without difficulty.

The anatomy of the several coats of the canal will be described in the succeeding chapters, but it may be mentioned at once that the submucosa alters but little throughout the alimentary tract, and that it is the most important site in the spread of carcinoma.

Lymphoid tissue is present in the canal in two forms, namely, solitary follicles and agminated or Peyer's patches. The latter are most numerous in the lower part of the small intestine, and as they form the vulnerable spot in typhoid fever, most of the ulcerations and perforations in that disease occur in the lower ileum. Peyer's patches are not found in the large intestine and but rarely in the stomach. They are more numerous in the child than in the adult (166). Solitary follicles, while occurring throughout the gut from stomach to anus, are in greatest number in the cæcum and appendix.

Lane and his co-workers have drawn attention to certain kinks which may be found associated with chronic intestinal stasis in the continuity of the gut. That these should actually be responsible for the stasis does not seem probable, for even when the splenic flexure is surrounded by adhesions, the kink thus formed produces no delay in the onward passage of the food. Indeed even in Guy's Hospital itself opinion is divided, for while Lane regards the kinks as the cause of intestinal stasis, others consider them to be rather the result of local peritonitis induced by the stasis (see 240). The sites at which Lane has localised kinks are the following (197):

1. Upper part of duodenum between transverse colon and gall bladder. It is to be noted that this is the site of the cysto-colic or cysto-duodenal ligament (see p. 122).

2. Lower part of duodenum. The probable explana-

tion of the appearances at this site is the compression of the gut between the superior mesenteric vessels and the aorta (see p. 119).

3. Near the termination of the ileum. This kink may be produced by adhesions in chronic appendicitis.

4. At the hepatic flexure.

5. At the splenic flexure.

6. In the pelvic mesocolon.

All of these may be due to pericolitis. Perhaps also it is well not to lose sight of the fact that kinks which are obvious at one time in a screen examination may have disappeared in half an hour.

Inspection of the abdomen may give some information concerning the site of the lesion in intestinal obstruction, for while the small intestine lies in the centre of the abdomen, the ascending and descending colons occupy the flanks. If obstruction occur in the ileo-cæcal region with consequent distension of the small bowel, the central part of the abdomen will be prominent, the flanks, which are occupied by the colon, being collapsed.

Obstruction at the splenic flexure causes distension of the right flank, but as the proximal colon is very distensible little or no effect is produced in the small intestine; hence the central part of the abdomen remains unchanged. Should obstruction be present in the pelvic colon, both flanks may be distended. Acute obstruction produced by volvulus of the pelvic colon causes great abdominal protrusion, which commences in the hypogastrium. For the pelvic colon is the most distensible part of the gut, and in a very few hours may become so dilated as to occupy most of the abdominal area.

In thin and emaciated individuals and in persons with chronic intestinal obstruction, peristalsis in the

alimentary tract may be observed through the abdominal wall. When the patient is in the recumbent posture, a wave of peristalsis above the umbilicus is suggestive of stomach movements. It is unlikely that any such waves are referable to the transverse colon, for even when sought by the use of the Roentgen rays movement in this part of the canal has been only rarely observed. Active peristalsis of the small intestine results in a zig-zag movement from the upper central to the lower central part of the abdomen. Indeed sometimes actual *ladder coils* of small intestine stand out in relief on the abdominal wall. Peristaltic waves pass so slowly or so rapidly along the large bowel that it is unlikely that they could ever be observed clinically through the abdominal wall (11). It is however well to avoid, or at any rate to limit, the use of the term peristalsis. So-called peristalsis of the stomach, segmentation movements in the small intestine, and antiperistalsis in the proximal colon are all similar and are responses of tonically contracted organs to stretching by contents. They constitute examples of a local response which does not require for its exhibition the integrity of the myenteric plexus; they are therefore independent of the myenteric reflex. Their function is to break up masses of food and to bring the nutritive material into closer association with the absorptive mucosa of the gut. Hence they pass food up or down the alimentary tract for a few centimetres only.

On the other hand, true peristalsis differs from the foregoing in that the stimulus is probably chemical rather than mechanical, and that a wave of inhibition always precedes the contraction, which, moreover, invariably progresses in the distal direction. Such a

movement depends upon the integrity of the nervous arc. If repeated encircling incisions be made through the musculature of the small intestine to interfere with the function of the myenteric nerve plexus which lies between the muscular coats, the movement is abolished (47). Such incisions in the stomach do not interfere with "peristalsis" in that organ for the reason already given.

Recently Kuntz has shown on morphological grounds, that these circular incisions need not interfere with the strictly local reflex response in the sympathetic arc, for he observed complete afferent and efferent neurones in the bowel wall so closely associated with each other (195) that the circular incisions could not interfere with their mechanism, which is of a more local character than that styled by Cannon the myenteric reflex.

Under certain conditions the true peristaltic (diastaltic) wave may advance at a very rapid rate. This is called the peristaltic rush. It is in some such way that intussusception is induced. When the nervous co-ordination breaks down in the death agony, reversed peristalsis and, in consequence, reversed intussusceptions may occur. The function of the true peristaltic wave is to pass on the nutritive material some considerable distance in the distal direction in order that fresh areas for digestion and absorption may be reached. Each kind of food is absorbed at different rates in different portions of the tract. Protein is absorbed most in the upper part of the absorptive area of the canal, though to a less extent in more distal situations. Starch and fat are absorbed in greater quantity in the lower part (213). Each portion of the gut absorbs of a particular food a constant percentage, which is independent of the amount taken

(212). But whether given in large or small amount, the entire absorptive area is active in the absorption of any particular variety of food stuff (211). The foregoing account indicates the reason for two distinct functions of the muscular coat of the alimentary canal, the movements in which have both been termed peristalsis. Cannon, therefore, proposes to use the word *diastalsis* for the true peristaltic wave, which is always preceded by a wave of inhibition and depends upon the myenteric reflex in the bowel wall. He would call the other movement, which has no preceding wave of inhibition, and which is independent of the myenteric reflex, *anastalsis* if it occur in the proximal direction, or *katastalsis* if directed distally (47). The term peristalsis is still useful, however, to indicate movement without definitely stating the character of the movement.

The nerve supply of the abdominal alimentary tract comes from the vagi, the splanchnics and the visceral pelvic trunks. The fibres in the vagi probably originate from the sympathetic nucleus of the vagus. The splanchnic fibres come from the sixth to the twelfth dorsal nerves inclusive, other branches of which supply the abdominal wall. The visceral pelvic trunks originate from the third and fourth sacral nerves, occasionally from the second also. These and the splanchnics reach the gut through the medium of the sympathetic plexus. The vagi and the pelvic trunks are tonic nerves, and the splanchnics are tonic inhibitory in function. Hence while the former increase the tone of the gut wall and cause the muscular coat to exercise a tension on the contents, the latter group has the opposite function. In man the vagi extend only to the neighbourhood of the termination of the ileum. These fibres are stated by some authors to terminate in

special nerve-endings, not in the myenteric plexus. But the pelvic nerves, which exercise a similar function on the distal colon, have not been proved to terminate otherwise than in the plexus. Whether in man the proximal colon receives any tonic nerves is doubtful. On the other hand, the inhibitory splanchnics extend throughout the tract.

Sensation in the alimentary canal (see 138) differs completely from that of the skin. The œsophagus and anal canal are both sensitive to thermal stimulations, while tactile sensation is present in the latter only. The sensations peculiar to the alimentary tract are burning, fulness, cramp, and hunger. Of these the burning sensation is that produced by alcohol. It is localised to the œsophagus and stomach, or possibly to the former alone, and is absent from the colon. It is probably the sensation felt in pyrosis. Fulness is caused by distension of the tract by gas. It is frequently associated with pyrosis in gastro-intestinal fermentation, and usually is produced by the evolution of carbon dioxide. Cramp-like spasms are due to the stimulating influence of gas, the most powerfully acting being carbon dioxide. Probably this is a stimulating factor in the production of multiple intussusceptions in the death agony (139). Hunger sensation is produced by muscular waves in a tonically contracted stomach (52). Its sudden onset and periodicity are thus explained. In duodenal ulcer the stomach is hypertonic and hence the presence of hunger pain in this disease.

In the alimentary canal three other responses to stimulation, which are reflex in character, must be mentioned. One of these, the abdominal wall reflex, is discussed in the first chapter (p. 11). But there are also

circulatory and respiratory responses. If the patient be not fully under the influence of the anæsthetic, manipulation of any part of the tract causes a fall in blood pressure, which is sudden in onset and which may reduce the patient to a very dangerous condition. It is probably, like the respiratory response, dependent upon the integrity of the vagi and pelvic nerves (48). Mechanical stimulation of stomach or anal canal under the same conditions produces in addition a deep inspiration or expiration, which calls for care on the part of the anæsthetist. Such a response does not occur in the small intestine or colon.

Localising sensations occur only in those parts of the tract which are relatively permanently fixed, that is, the stomach, duodenum, and large intestine. They are produced by local peritonitis of the parietal peritoneum, the involvement of which follows a focal lesion of the mucosa in a fixed portion of the tract. Lennander explains pain from ulcer of stomach or intestine as the result of inflammation of the lymphatic vessels and nodes which drain the affected area (200). Sensation in the small intestine is vague and is referred to the neighbourhood of the umbilicus, which is supplied by the tenth dorsal nerve, one of the main nerves which supply the jejunum and ileum. Hence when a gall stone is obstructing the duodenum, the pain is fixed and localised to the epigastrium, but as the stone passes through the jejunum and ileum, the pain loses its fixed character and is referred vaguely to the region of the umbilicus.

The vascular supply of the abdominal tract is simple. The stomach and the proximal part of the duodenum as far as the entry of the bile duct are supplied by the cœliac axis artery and its corresponding veins. The

remainder of the duodenum, the jejunum, ileum, cæcum, and colon as far as the splenic flexure receive their supply from the superior mesenteric vessels. The distal colon, including the rectum, is supplied by the inferior mesenteric vessels and their branches. It is to be observed that, contrary to the usual belief, valves are present in the veins of the portal system. These are best marked in infancy and tend to become incompetent in adult age. Wilkie recently redirected attention to this fact and showed the presence of competent valves in the gastric and omental veins of some adults and even in the veins from the large intestine of the new-born child, in which they are most numerous in the veins of the pelvic colon (346).

CHAPTER V.

THE ŒSOPHAGUS.

THE œsophagus, as the continuation of the pharynx, commences in front of the body of the sixth cervical vertebra, and terminates in the cardiac orifice of the stomach at the left side of the body of the eleventh dorsal vertebra. The precise sites just given for commencement and termination are those usually found in the adult male. The course of the œsophagus lies in the lower part of the neck, in the superior and posterior mediastina of the thorax, and for a distance of about 2·5 cm. in the abdomen. The length of the gullet is usually stated to be 20 to 25 cm. in the normal adult, varying with the length of body. There are, however, considerable individual differences in the length of the œsophagus. Besides having relation to the height of the vertebral column, these differences depend, in addition, upon the exact level of the pharyngo-œsophageal junction and upon the site of the cardia. In the infant the œsophagus commences opposite the lower border of the fourth cervical vertebra. The level of its commencement gradually sinks during childhood, and attains the adult position at puberty. During the first two years of life, the œsophagus is very long compared with the height of the body. After the twentieth year the ratio between the length of the œsophagus and that of the body becomes stationary. In later life there is again a relative lengthening of the gullet. The average length of the œsophagus is given by Kolster as 22–26 cm. in the adult female, and

25–30 cm. in the adult male. More variable than either the length of the vertebral column or the level of the commencement of the gullet, is the site of termination of the latter at the cardia. In a series of adult females Kolster found the highest site of the cardia at the left side of the tenth dorsal vertebra in a woman of twenty-four years, and the lowest in a female cadaver seventy years of age at the level of the first lumbar vertebra. The highest site among adult males was at the level of the ninth dorsal vertebra in a man of thirty-one years, and the lowest opposite the first lumbar vertebra in a man of eighty-two years. Generally speaking, there is a sinking of the cardia with increasing age. This lowering of its position does not progress regularly, but is somewhat more regular and earlier in males than in females. There is also a very small variation which depends upon the state of distension of the stomach.

As a rule the cardia lies slightly higher in females than in males.

The surface markings for the œsophagus in the adult may be expressed in a general manner as follows :—

Front, from the cricoid cartilage to a point on the seventh costal cartilage of the left side 2·5 cm. from the median plane.

Back, from the spine of the sixth cervical vertebra in the middle line to the left side of the spine of the eleventh dorsal vertebra.

Allowance must be made, however, for the individual differences already mentioned. (For further information see Kolster (192).)

Practically the only curve shown by the œsophagus in an *x*-ray examination during life is an antero-posterior one which corresponds with the curve of the vertebral

column. In the cadaver it is seen that from its commencement to the cervico-dorsal junction the gullet inclines somewhat to the left. It again reaches the middle line at the level of the disc between the fourth and fifth dorsal vertebræ. This level is indicated on the surface by the angle of Ludwig between the manubrium and the body of the sternum. From this point downward the gullet again passes slightly to the left to reach its termination at the cardia.

In the neck the gullet lies in front of the bodies of the lower two cervical vertebræ, and has the trachea as a ventral relation. On each side lies the carotid sheath with its contained vessels and nerves and the sympathetic chain immediately dorsal. The thyroid gland also overlaps the œsophagus laterally, while the recurrent laryngeal nerve passes upward on each side between the trachea and the gullet. Enlargements of the thyroid gland may interfere with swallowing. As the gullet lies slightly toward the left at the cervico-dorsal junction, œsophagotomy in the neck is usually performed on this side. In cervical œsophagotomy care must be taken of the inferior thyroid artery behind the carotid sheath. In the thorax the œsophagus also lies on the vertebral bodies, inclining somewhat toward the left above and below the fifth dorsal vertebra. In front of the œsophagus above the fifth dorsal vertebra lies the trachea. Below this point the pericardium forms an immediate ventral relation to the gullet, and separates it from the left atrium (auricle). Opposite the fifth dorsal vertebra the left bronchus passes in front of the gullet, and may be involved in or perforated by œsophageal carcinoma in this situation. Here also the commencement of the descending aorta courses over the left side of the

œsophagus to pass downward as a left lateral and somewhat dorsally-placed relation of the gullet. The descending aorta prevents the left pleura from coming into close relation with the œsophagus. The gullet is clothed on its right side and partly on its dorsal aspect by the parietal layer of the right pleural sac, from the fifth dorsal vertebra as far as the diaphragm, the œsophageal opening in which is usually stated to lie opposite the tenth dorsal vertebra. The intimate relation of the gullet to the left bronchus, aorta and right pleural sac at the level of the fifth dorsal vertebra is very important in view of the occurrence of œsophageal carcinoma at this site. Such a growth may involve or ulcerate into any of the three cavities with disastrous results. The aorta may be the seat of an aneurysm which ultimately leaks into the gullet. Immediately surrounding the œsophagus is the cellular tissue of the superior and posterior mediastina, which may be the site of a fatal cellulitis or of a localised abscess resulting from an œsophageal lesion. On each side of the thoracic œsophagus lies the vagus nerve, which forms the œsophageal plexus in the posterior mediastinum. In the lower part of the thorax the left vagus comes to lie on the ventral aspect of the gullet, while the right vagus inclines toward the dorsal surface.

For operative purposes the relations of three other structures are important. The azygos vein ascends on the right side of the gullet to the level of the fifth dorsal vertebra, where it passes forward above the root of the right lung to terminate in the superior vena cava. Between the azygos vein and the gullet lies the thoracic duct, which gradually inclines toward the middle line to lie dorsal to the œsophagus in the adjacent parts of

the posterior and superior mediastina. It ultimately reaches the left side of the gullet at the root of the neck. Last, on a posterior plane lie the sympathetic chains, one on each side, ventral to the necks of the ribs.

Certain anomalies, when they occur, may present an important relation to the œsophagus. These are accessory thyroid glands lying dorsal to the gullet, and an abnormal right subclavian artery arising from the left portion of the aortic arch and passing to the right. The latter structure may present a ventral or dorsal relation to the œsophagus, passing between it and the trachea or vertebral column (166).

If a periœsophageal abscess exists in the dorsal region, yet does not extend below the level of the third dorsal vertebra, Kocher advises that cervical mediastinotomy be performed. Both heads of the sternomastoid are divided. If the incision is made on the left side, one proceeds behind the sterno-clavicular articulation along the lateral aspect of the vessels of the neck. If on the right side, the abscess is reached between the carotid artery and the internal jugular vein.

In dorsal mediastinotomy Bryant believes in performing the operation on the left side if the œsophagus above the level of the aortic arch is to be reached. The aortic arch corresponds on the back with the spine of the fourth dorsal vertebra. If below this level but above the ninth dorsal vertebra, Bryant would do the operation from the right side. Rehn and Potard point out that the important relation is the aorta, which is best avoided by operating from the right side. The wrapping of the pleura round the œsophagus on this side is of little consequence, for injury to the pleura, as pointed out by Heidenhain, is not a matter to cause anxiety. In doing

the operation it is necessary to watch for the azygos vein, for the vagus nerve and for the sympathetic chain, the last of which, at this level, lies close to the lateral aspect of the vertebral bodies.

Below the level of the ninth dorsal vertebra, the œsophagus is too deep to be reached without difficulty.

The thoracic œsophagus between the levels of the fifth and ninth dorsal vertebræ can be reached by traversing the pericardium. Jaboulay's method for doing this is to incise the ventral wall of the pericardium throughout its whole length and to push the heart aside. The gullet may also be reached by a trans-pleural operation.

Sauerbruch's method is to make an incision in the third right intercostal space to reach the œsophagus above the root of the right lung (fifth dorsal vertebra). To reach the lower œsophagus he makes the incision in the fourth or fifth left space. In performing resection of the thoracic œsophagus, Sauerbruch states that the vagi must be carefully avoided (but see p. 107).

(Further information on œsophageal operations is to be obtained from Kocher (191).)

The œsophageal orifice of the diaphragm in the adult is usually at the level of the ninth dorsal spine.

The standard measurements of different sites in the gullet from the upper incisor teeth are the following :—

Commencement, 15 cm. (6 in.).
Crossing of left bronchus, 22 cm. (9 in.).
Diaphragmatic opening, 35–37 cm. (14–15 in.).
Cardiac orifice, 40 cm (16 in.).

All of these, but especially the last two, are liable to considerable variation.

The distances along the œsophagus from the upper

incisor teeth to the levels of the various dorsal spines are thus given by Kocher (191):—

1st dorsal spine	... ...	8 in.
2nd ,, ,,	... ...	$8\frac{3}{4}$ in.
3rd ,, ,,	... ...	$9\frac{3}{4}$ in.
4th ,, ,,	... ...	$10\frac{1}{4}$ in.
5th ,, ,,	... ...	11 in.
10th ,, ,,	... ...	$15\frac{1}{2}$ in.

One has only to compare this table with the previous one to see how very unsatisfactory are all arbitrary measurements.

The lumen of the œsophagus in the neck is compressed dorso-ventrally to form a transverse slit. In the thorax the lumen is more circular. This is said to be due to the negative pressure in the chest.

The calibre varies in different situations. It is narrowest at the commencement, where indeed it forms the most constricted part of the alimentary canal (20). Other narrow places in the œsophagus are at the level where the left bronchus crosses the organ, and where the gullet traverses the diaphragm. The former of these sites is indicated on the chest wall by the angle between the manubrium and body of the sternum, and on the back by the fourth dorsal spine. The topography of the latter site is, ventrally, the xiphoid process, and dorsally, the overlapping ninth thoracic spine. Mehnert (232) cites as many as thirteen constrictions in the œsophagus, but these, no doubt, are due to physiological waves of peristalsis fixed in death. Mehnert concluded that the average minimum diameter of the gullet is about 14 mm., but that it may be reduced in a normal adult to 11 mm.

The site of the junction of the upper and the lower

gullet lies practically at the bronchial constriction throughout life. In adults and children, foreign bodies are liable to lodge there. Two cases of the presence of a coin in the œsophagus are recorded by Haslam. Thus in one of these, a child aged five years, the coin could be seen by radioscopy to lie at the level of the sternal end of the second costal cartilage (angle of Ludwig). In the other, a child aged three years, the coin could be plainly seen behind the upper part of the manubrium (129).

The diameter of the œsophagus below the constriction at the level of the bronchus is often much greater than the diameter above this level even in quite normal bodies. This is so marked that one may distinguish an upper and a lower gullet, which, furthermore, present marked differences in the muscular coat, the upper gullet musculature being striped, while that of the lower gullet consists of unstriped fibres. Mehnert cites a case in which the lower gullet possessed a diameter double (*i.e.*, 37 mm.) that of the upper œsophagus (232).

The dilatation of the lower gullet is better marked in apes than in man, and is stated to be absent in the fœtus, although I have seen indications of its presence in late fœtal life. According to Cunningham it appears only when the œsophagus is functionally active (77). The dilatation was called by Cunningham the phrenic ampulla. Luschka, Blasius and others have written concerning this portion of the œsophagus, the former having mentioned its occurrence in " ruminating men " (219). It is stated to consist of the last 3-4 cm. of the œsophagus above the diaphragm. A similar instance has been recorded by Keith and Wood Jones as a hernia of the cardiac part of the stomach (186). This peculiar formation of the lower gullet has been discussed by

Strecker under the title of Vormagen (319), a term which is undesirable in consequence of its being used with different meanings by various writers.

The exact significance of the lower gullet is not yet fully understood. Indeed it would seem that it presents different characters and functional value in different individuals. In cardiospasm it frequently becomes greatly distended, and in some cases of so-called gaseous distension of the cardiac end of the stomach, it is probable that the palpitation is due in part to the presence of gas in the lower gullet in virtue of its position relative to the left atrium. The occurrence of distension in this portion of the gullet can more readily affect the heart's action than can the presence of gas in the stomach. So important may the lower gullet become in clinical work that Strecker pleads for its inclusion in the stomach system. Rupture of the wall of the healthy œsophagus is very rare, but when it does occur, the wall gives way just above the diaphragm (335).

In structure the œsophagus is a muscular tube, presenting an outer coat of longitudinal fibres and an inner coat composed of circular fibres.

The short intra-abdominal portion possesses a serous covering of peritoneum. The right side and part of the dorsal aspect of the thoracic portion are covered by the serous parietal layer of the right pleural sac.

In the upper gullet both muscular coats are composed of striped fibres. The circular bundles are continuous with those of the inferior constrictor. The longitudinal fibres form two bundles more or less lateral in position in the upper part of the tube, and are attached to the cricoid cartilage as a fixed point (1). There are weak places where the muscular fibres are few, in V-shaped

areas just below the inferior constrictor behind and the cricoid cartilage in front.

Associated with these weak places is the occasional presence of hernial pouches or diverticula at the upper end of the gullet. As a rule, the pouch is on the dorsal wall, and when distended with contents, it may block the passage of food along the œsophagus. A pouch in this situation may sometimes be identified by *x*-ray examination (140). According to Butlin the condition is more frequent than has been supposed, and becomes clinically important, as a rule, in men beyond the age of forty (45).

According to Killian, the *globus hystericus* is caused by the spasmodic contraction of the circular fibres at the upper orifice of the œsophagus, and is the chief cause of the diverticulum just mentioned (189). A certain thickening of circular muscular fibres at the commencement of the œsophagus forms a functional sphincter, and except in swallowing, keeps the orifice of the gullet closed by approximating the dorsal wall to the cricoid cartilage. According to Killian, this "sphincter," like the cardia, contracts through the influence of the sympathetic nerves. Relaxation is brought about by the action of the vagus.

A diverticulum is occasionally found on the ventral wall near the bifurcation of the trachea, and is stated to be due to traction on the gullet consequent on the cicatrisation of adhesions to inter-tracheo-bronchial lymph nodes.

One other malformation of the œsophagus may be mentioned besides the diverticula. This is produced by abnormal conditions of the tracheo-œsophageal septum. The trachea and bronchi are developed from a groove in the ventral wall of the œsophagus, and are ultimately separated by lateral ridges which meet and divide off

the groove from the dorsal part of the œsophagus; the latter becoming the true gullet. These ridges may, however, pass dorsalward and shut off a small pocket above from a lower tube which represents both trachea and œsophagus. Hence food in such cases can only reach the stomach by passing along the common tube, which represents trachea and œsophagus combined. The condition is incompatible with life, and has been discussed by Keith and Spicer (185).

In contradistinction to that of the upper œsophagus, the musculature of the lower gullet is composed of smooth fibres. The transition between the two forms of musculature occurs in the heart region, and in this respect the œsophagus of man corresponds with that of the cat (262). In considering the results of experiments on the œsophagus of animals in relation to homo, one must always bear in mind the different anatomical characters of the œsophagus in the various laboratory animals. In the dog, for example, the musculature of the gullet is striated throughout its length, and thus differs from that of the cat and of homo.

The œsophagus exhibits muscular tendrils, which pass from its walls to neighbouring structures, vertebræ, aorta, bronchi and pleural sac. Some of these tendrils are grouped together to form definite bundles as in the case of the broncho-œsophageal and the pleuro-œsophageal muscles. Of these the latter connects the gullet with the left pleural sac and is said to be constant. These tendrils consist of smooth muscle or elastic tissue, and spring from the longitudinal muscular coat of the gullet. They are homologous with similar fibres found throughout the mesentery of the small intestine.

At the termination of the œsophagus there is a slight

reduplication of circular muscular fibres which forms a rudimentary sphincter. Regurgitation from stomach to œsophagus is prevented by the sharp angle at the cardiac orifice and by the muscular tissue of the diaphragm in addition to the action of the so-called cardiac sphincter just mentioned (150).

The mucous membrane of the œsophagus is rose-coloured during life. It presents longitudinal rugæ, which are much better marked in the cadaver than in the living. It is lined by stratified squamous epithelium. The presence or absence of glands in the mammalian œsophagus is apparently connected with the chemical constitution of the food rather than with its physical character. Often demilunes are present. Hence serous secretion occurs as well as mucous. In man there is great variability in the number of glands, with cyst formation and atrophy, which are interpreted by Goetsch as a suggestion of the gradual disappearance of œsophageal glands (114). In this respect man again resembles the cat which possesses no glands rather than the dog which has many glands throughout the length of the gullet. In man the œsophageal glands are more numerous as a rule in the lower gullet (301). Schaffer has claimed an amylolytic action for the glands in the lower gullet (302).

The vascular supply of the œsophagus presents no points of clinical significance other than the dilatation of veins near the cardia, which will be considered in the chapter on the stomach.

The lymphatics of the cervical portion of the gullet pass to the substernomastoid nodes. Those of the thoracic portion drain into the mediastinal (periœsophageal) nodes. The nodes along the lesser curvature of

the stomach extend in a chain continuous with those of the posterior mediastinum through the œsophageal orifice in the diaphragm.

The lymphatic network of the cardiac portion of the stomach is continuous with that of the lower gullet (272). On the other hand, there is no corresponding free communication between the lymphatic plexuses of adjacent parts of the pharynx and upper gullet (272).

The œsophagus is supplied by branches from the glossopharyngeal and vagus nerves, and also by sympathetic filaments. According to Head, most of the sympathetic fibres going to the thoracic œsophagus arise from the fifth dorsal segment, but this part of the gullet receives in addition fibres from the sixth, seventh and eighth dorsal segments (133). This explains the referred pain produced by œsophageal lesions in the area supplied by the fifth dorsal spinal nerve. The vagus is the tonic nerve, and the glossopharyngeal the tonic inhibitory nerve to the gullet. By the influence of the vagus the normal tone of the œsophagus is maintained, and waves of peristalsis are produced. The severing of both vagi results in complete temporary paralysis of the œsophagus. The animal used in this experiment was the cat, the œsophagus of which corresponds closely to that of homo, as already indicated. After an interval of a day or two complete peristaltic activity was restored in the lower gullet; the upper œsophagus remaining paralysed. Cannon investigated the conditions in the monkey (*macacus rhesus*) as well as in the cat, with similar results. The lower gullet, the wall of which is composed of smooth muscle fibres, is capable of exhibiting peristaltic waves in the absence of extrinsic nervous mechanism. Apparently the activity is roused

by local stretching of the œsophageal wall. The capacity for exhibiting tension when stretched is ordinarily maintained by vagus influences, but may be intrinsically developed when these influences are lost. Similar experiments in the dog and the rabbit do not give the results obtained in the case of the cat. In these animals the œsophageal wall consists throughout of striped fibres (48).

The cervical œsophagus obtains its tonic nerve supply from the recurrent branches of the vagus. Hence if these nerves are left intact in the above experiments, food is still normally passed as far as the commencement of the thoracic œsophagus.

The capability of development in the lower gullet of peristalsis independent of extrinsic nerve influences enables the operation of partial œsophagectomy to be performed without a consequent paralysis resulting in stagnation of food in the gullet and stomach (see also p. 107).

The glossopharyngeal nerve, as already mentioned, exercises a tonic inhibitory influence on the gullet. If this nerve is cut, the œsophagus undergoes temporary tonic contraction. Radiographic examination shows that rapid peristalsis occurs in the upper portion of the œsophagus, while slow peristalsis only is exhibited by the lower gullet. This is to be expected from the character of the muscular fibres in the two parts.

Food passes through the œsophagus in from four to nine seconds ($4^2/_5$ to $8^3/_5$ seconds, Hertz). Half of this period is occupied by the passage of food from the lower gullet into the stomach (141). According to Hertz, the first food sound is produced by the impact of fluid against the dorsal pharyngeal wall, or the contraction of

the muscles in swallowing a mass of food (142). The second sound, as a rule, is heard only after the swallowing of fluids. It occurs occasionally after solids have been taken, but this is probably due to the bolus being semi-fluid through admixture with saliva. It occurs 6·7 seconds after swallowing, and is heard in maximum intensity through the stethoscope placed against the back to the left of the ninth dorsal spine, that is to say, at the level of the œsophageal orifice in the diaphragm. As the second sound is heard only after all trace of fluid has left the œsophagus, its explanation is difficult. Hertz suggests that it may be due to the forcing of gas from the stomach into the gullet in consequence of the raised pressure in the former and the lower pressure in the latter organ (142).

The function of the circular muscular fibres at the lower extremity of the gullet are (1) tonic contraction, (2) rhythmic alternate contraction and relaxation.

Stimulation of the vagus results in inhibition of the "cardiac sphincter" with subsequent increase in tone. There is, however, some evidence to show that the cardia has a sympathetic supply which causes relaxation (48).

A number of successive swallows will cause relaxation of the cardia. Relaxation with contraction of the stomach in the dog occurs also when the intragastric pressure rises to 25 cm. of water (188).

When the cardia is irritated mechanically or chemically, the tonic contraction of the "sphincter" is increased and cardio-spasm occurs. When this condition is present, cold drinks and carbonated water have greater difficulty than warm water in entering the stomach (237).

Normally the rather low degree of tonic contraction of the cardiac ring is assisted in the locking of food in the

stomach by local mechanisms. Just as the presence of acid in the duodenum results in the closure of the pyloric sphincter, acid contents in the cardiac sac may keep the cardia closed (48). With deficiency of hydrochloric acid in the stomach, there is a corresponding relaxation in the cardiac ring. For this reason certain consumptives easily regurgitate gastric contents during a coughing bout (234). The peristaltic waves of the lower gullet assist in retaining food in the stomach. In the intervals of gastric digestion and during the night, relaxation of the cardia is more marked. Kast observed that after the night's sleep the bad taste in the mouth and the coating of the tongue in gastric disturbances are produced by the return of partly digested bits of food, leucocytes and epithelial cells along the œsophagus through a relaxed cardia. These are spread to the mouth by the pump action of the diaphragm and the intra-œsophageal alterations of pressure produced by respiration and the heart beat (172). There is no antiperistalsis in the œsophagus.

As Cannon points out, the coated tongue is found especially in cases of abnormal fermentation of gastric contents, which results from deficient hydrochloric acid. This is precisely the condition for a relaxed cardia.

The eructation of gas with regurgitation of fluid is produced by the effect of the gas in keeping acid contents away from the stomach wall in the region of the cardia. The cardia relaxes and permits the passage of gas, while acid fluid may also escape before the "sphincter" again closes. Attention has already been called to the possibly important effect upon the heart which results from the presence of gas in the lower gullet, especially in conditions of extreme weakness.

Sensations in the œsophagus may be summarised in the following manner. The gullet has no tactile sensibility. Carminatives, hydrochloric, lactic and acetic acids produce no sensation in it. The œsophagus is sensitive to thermal stimulation. Indeed the sensations of heat and cold experienced in the epigastrium on the swallowing of hot and cold fluids respectively are produced in the lower part of the œsophagus. Alcohol produces a burning sensation in the gullet. Heartburn may be produced by the regurgitation of the alcoholic products of fermentation into the lower gullet through a relaxed cardia (138).

CHAPTER VI.

THE STOMACH.

WHEN seen in the operating theatre or post-mortem room, the stomach frequently presents the appearance of a saccular viscus. This does not represent the normal condition during life. It is the result of atony in the

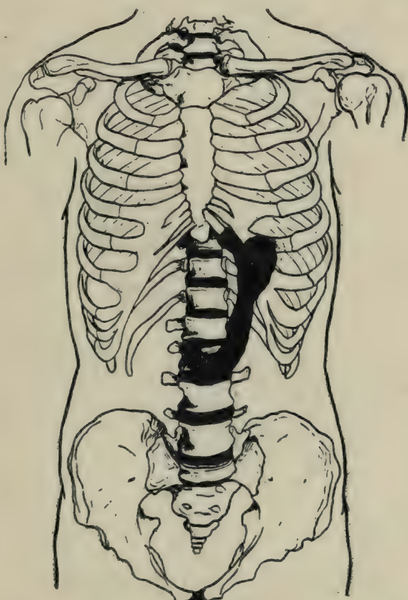


Fig. 6. Tracing of normal empty stomach from cadaver embalmed with formalin.

The typical narrow tubular appearance of the empty stomach is well seen.

muscular tissue of the stomach wall (12). On occasion, however, the normal shape of the stomach as observed in x-ray examinations is preserved at autopsy; it is most likely to be encountered in post-mortems conducted within a very short time after death has occurred. Such a stomach was figured recently by Stopford (318). The organ presents a shape like the letter J. The greater part of the stomach is contracted to form a narrow tube.

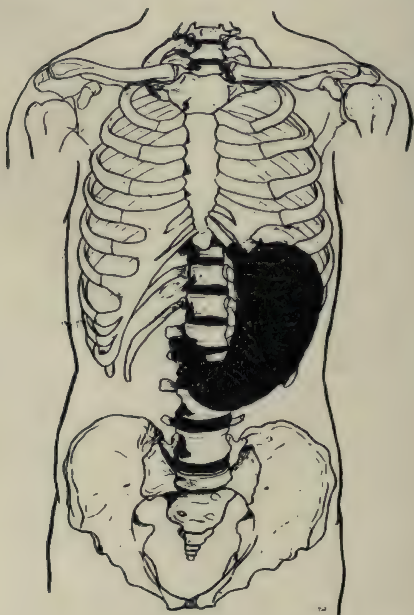


Fig. 7. Tracing of normal distended stomach from cadaver embalmed with formalin.

Comparison with fig. 6 shows that on distension of the stomach the greater curvature does not descend to any great extent; the organ distends laterally through the burrowing of the greater curvature between the layers of the greater omentum.

At the upper end of the longer limb of the J, is a small saccular portion distended by the gas which it always contains (Mägenblase).

The J-shaped stomach occurs in about 80 per cent. of adult individuals. Groedel calls it the syphon-form. He distinguished descending and ascending limbs, with an intermediate "Magensac" corresponding to the pyloric vestibule, to which reference will be made later. Groedel further points out that the form of the stomach depends in part upon the position of the body. The organ presents a syphon-form if the patient is standing erect, while it assumes a sandal-shape when the individual is in the recumbent posture (117). The stomach is observed in its usual and most natural working position if the patient is examined standing up. Many variations in both site and form occur in the normal organ, and for this reason exact measurements cannot be given. The descending limb always lies to the left of the middle line; it is placed almost vertically when looked at from the front, although if observed from the side it will be seen to be directed somewhat forward. In many cases there is a slight inclination to the right. The shadow of the lesser curvature, as pointed out by Rieder, frequently coincides with the left border of the shadow cast by the vertebral column (284). The ascending limb (pyloric canal) usually lies to the right of the middle line in *x*-ray examinations. It may, however, lie to the left of the middle line, especially when the cæcum and ascending colon are distended with gas. The position of the stomach is much influenced by gaseous distension of the proximal colon or splenic flexure. According to Groedel, two-thirds of the magensac (pyloric vestibule) lie to the left, and one-third to the right of the middle line (117).

In most individuals, the pylorus does not form the lowest portion of the stomach as was stated to be the case by Holzknecht (152). The stomach is movable round an axis which passes through the cardia and the pylorus. Rieder further points out that the most dependent portion of the stomach in females may be considerably lower than in males, and that the site and form of the organ are by no means stationary in any individual (284). The slight differences to be noted between the account given by Stopford and those quoted from Rieder and Groedel are accounted for by the fact that whereas Stopford's example was a practically empty stomach, the organs examined in life by the two latter authors were of necessity partially filled with bismuth-containing food. That the presence of bismuth in the stomach has no effect in producing distortions in the shape of the organ has been shown by Groedel and Hasse in their experimental feeding of powdered bone instead of bismuth to the patient. The *x*-ray appearances were exactly similar whichever of these substances was used (99). A less frequent though still normal form of stomach is that known as the Holzknecht type, or *cowhorn* stomach. In this variety (20 per cent. of individuals) the pylorus is the lowest part of the organ.

There is no sharp distinction between the normal organ and a pathological stomach. Neither relative enlargement of the pyloric vestibule nor the size of the stomach can be depended upon for diagnosis of a pathological state. There is a gradual progression from the normal to a pathological form without the development of a new type (117). The form of the normal stomach is not by any means constant, and it frequently requires considerable experience to decide whether a given organ is normal or not.

Some general directions for the recognition of the normal organ will be given later.

Recently there has been much controversy over what is to be considered the "normal" subdivision of the stomach. The views of different writers have been biassed by their methods. Some have occupied themselves solely with fœtal stomachs; some with post-mortem appearances of the adult organ; others again have based their descriptions upon *x*-ray examinations. These partial investigations have resulted in the description as normal of a variety of appearances. Wernstedt regards the time-honoured simple saccular stomach of the older anatomists as the real shape of the organ, and classes all other appearances as "contraction forms" (341). Paterson, going to the other extreme, regards the stomach as being normally a four-chambered organ (267). The recent article by Schwalbe gives the most complete account of the stomach, and is based on the observation of material from fœtus, child and adult; the *x*-ray appearances of the living organ being carefully harmonised with the condition of the organ in the dissecting room and post-mortem theatre. Schwalbe regards the stomach as consisting essentially of two portions:—

(*a*) the saccus digestorius;

(*b*) the canalis egestorius.

Of these the saccus digestorius further presents a subdivision into:—

(i) a saccus cardiacus;

(ii) a corpus ventriculi or tubus gastricus.

The canalis egestorius (which Schwalbe also terms the pars pylorica) may present a dilated portion corresponding to the *Magensac* of Groedel and a more contracted portion, the pyloric canal (305).

Reference to the accompanying figure will render more clear the somewhat complicated nomenclature of the stomach.

The extreme upper portion or dome of the cardiac sac is formed by the fundus proper. This is always distended with gas and is known as the *Magenblase.*

Fig. 8. Tracing of hypothetical stomach to illustrate the nomenclature. A, saccus digestorius; B, canalis egestorius (pars pylorica), (i) saccus cardiacus, (ii) corpus ventriculi or tubus gastricus; b, magenblase; s, magensac or pyloric vestibule; p, pyloric canal; P, pylorus; I, incisura angularis; U, sulcus intermedius; D, Duodenal cap or bulb.

The fundus proper merges insensibly into the main portion of the cardiac sac, although occasionally a slight indentation of the greater curvature may indicate the junction of the two.

Beyond the cardiac sac the gastric tube (tubus gastricus—Schwalbe), a more or less narrowed portion, is to be observed. This leads to the *Magensac* of Groedel, otherwise known as the *pyloric vestibule* of Cunningham (77). The gastric tube becomes more capacious with

the filling of the stomach, and may show smaller indentations along the greater curvature. These are post-mortem indications of the waves of peristalsis. It has been suggested by Schwalbe that they are analogous but not homologous with the sacculations found in the large intestine.

As the gastric tube is the portion of the stomach in closest relation to the upper pole of the left kidney, it is possible that the latter organ may have some mechanical relation to a dorso-ventral flattening of the walls with consequent diminution of the lumen in the region of the gastric tube. There would seem to be some basis for such a suggestion in the radiographic appearances noted in certain cases of gastroptosis (13).

Distal to the gastric tube, the stomach presents a portion which may or may not be distended according to its relative fulness, and for which Cunningham's term *pyloric vestibule* would seem on the whole the happiest. This is separated distinctly from the preceding portion of the stomach by the incisura angularis on the lesser curvature. There is, as a rule, no special subdivision on the greater curvature. But here a spasmodic constriction may be present, and is thought by some writers to be a constant feature of the stomach in certain stages of digestion. It is especially emphasised by Gray (115). The pyloric vestibule is succeeded by the pyloric canal, a frequently contracted and tube-like portion of the stomach with a length in the adult of 3 cm. It is marked off from the pyloric vestibule by an indentation along the greater curvature known as the *sulcus intermedius*. There is no delimitation of the pyloric canal from the pyloric vestibule on the lesser curvature.

In addition to these subdivisions of the stomach, it is

necessary to mention a peculiar formation termed by Waldeyer the *Magenstrasse* (336). Retzius, in 1857, pointed out that there is a portion of the stomach lying along the lesser curvature which can be separated off from the remainder of the organ. Thus a kind of tube is produced along which fluids and soft food may pass direct to the pyloric part without necessarily going through the cardiac sac, and the observation was confirmed by Luschka. The tube was supposed by Retzius to be homologous with the *œsophageal groove* in the stomach of ruminants (280). Sisson and the workers in his laboratory, however, throw doubt upon this function of the œsophageal groove of ruminants (310), believing rather that the muscular limbs bounding the groove have the function of drawing the œsophageal orifice and the reticulo-omasal opening together. Kaufmann showed that there is no indication of this *Magenstrasse* in the empty stomach, but that it can be found in the artificially contracted organ. How far contraction of the limiting muscular fibres of this groove can cut it off from the rest of the stomach is not at present known. Luschka stated that a complete tube may be formed, and Kaufmann mentions that he has no evidence to disprove Luschka's assertion (174).

Cohnheim was the first to show (in the dog) that after the stomach is filled, water swallowed by the animal does not mix with the acid gastric contents, but flows by a short path along the lesser curvature directly from the cardia to the pyloric part, and even through the pylorus into the intestine (65). But no shortening of the lesser curvature is noticed during this act.

All the foregoing description has been based upon the examination of adult stomachs. But the investigation of

the organ in the fœtus and new-born child confirms the principal points to which reference has been made. That the form assumed by the living organ is not entirely due to muscular contraction is shown by Lewis, who states that the mucous membrane in the stomach of embryos between 10 and 45 mm. in length has already the characteristic shape to which the other layers subsequently conform (202). Lewis also remarks that the subdivision of the stomach into cardiac and pyloric portions long ago described by Home (153) is well marked in embryos in which the muscle layers are scarcely differentiated. While the *Magenstrasse* may be shown as early as this, it is not to be found in all embryos (202). The earliest embryonic stomachs merely contain clot mixed with epithelial cells; later fluid contents distend the organ, and in the post-mortem appearance of such a specimen, even the limitation between cardiac and pyloric parts may be lost (embryo at 125mm. stage—Schwalbe), the gastric tube formation being entirely wanting (305).

In the stomach of the new-born child, the *x*-ray picture and the post-mortem condition may closely resemble the appearance illustrated by His's model of the adult stomach. It approximates to the sandal-form which is seen in the adult when the recumbent posture is assumed. The stomach of the infant, however, may present the features already described as characteristic of the adult organ. This does not indicate a tendency to bilocular formation, as was thought to be the case by Delamare and Dieulafé (80). Congenital bilocular stomach has frequently been recorded and as often refuted. It was stated by Moynihan to be invariably pathological (249). Brook, however, recorded a case in which the isthmus

possessed a muscular coat no thicker than that of any other neighbouring portion of the stomach. The peritoneum, omenta and mucous membrane and the pylorus showed no thickening, puckering, cicatrix or other evidence of a pathological condition. For this reason, Brook regarded congenital bilocular or hour-glass stomach as a possibility (42). Moynihan admits that the hour-glass stomach may have been congenital in Brook's case (250). But the condition, in this instance also, was probably pathological. The statement of Lewis that the occurrence of an accessory pancreas on the lesser curvature may account for a permanent stricture between the cardiac and pyloric parts of the stomach, is particularly suggestive in this connection (202).

Alteration in Shape of the Stomach dependent upon Age, Sex, Position, Digestion and other Factors.

The shape of the stomach varies considerably even within normal limits, so much so that, as previously stated, no measurements can safely be given for the limitation of the normal organ. The portion which alters least in shape (although even it changes its position) is the pyloric canal.

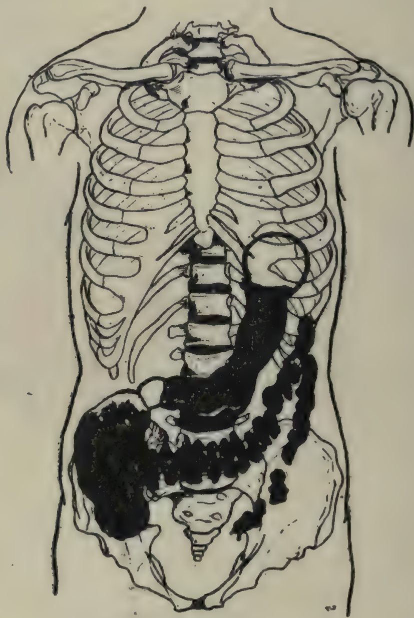
The stomach in the infant approximates more to the sandal-shape than to any other form mentioned. In view of the relatively small capacity of the abdomen, the comparatively large size of the liver, the distension to a greater or less degree of the various portions of the alimentary canal with gas, and because the action of gravity has not yet been fully exerted in the erect posture on the organ, the stomach does not present the syphon-form, nor even the cowhorn-shape so typical of the adult.

It is pressed high up in the abdomen under the diaphragm and liver by the other viscera. The pyloric part is more horizontal than in the adult, and the incisura less marked. The incisura is only formed toward the end of fœtal life through the bend in the lesser curvature becoming sharper (305). The difference in extent between the cardiac and the pyloric portions of the stomach, as indicated by the site of the incisura angularis, is not so marked in the new-born child as in the adult, and in the former the condition seen is reminiscent of that in the anthropoid apes (343). With the enlargement of the abdomen, the relative decrease in size of the liver and the increasing influence of the action of gravity, the stomach assumes its characteristic adult shape.[1]

The J- or syphon-form is more exaggerated, and all parts of the stomach except the cardia tend to lie at a slightly lower level in the adult female than in the male. In the male the stomach is shorter and more obliquely placed; in the female it is more vertical, the proximal limb of the J is longer, the pyloric vestibule broader and the distal limb (pyloric part) shorter. Irregularities in form are more common in females, particularly an indentation in the proximal limb, said by Groedel to correspond to the waist (117). These remarks refer, naturally, to the radioscopic appearance of the stomach when the patient is standing erect. When the patient is examined in the recumbent posture, both shape and situation of the stomach are altered. The shape approximates to the sandal-type, and the whole organ lies at a higher level. The pylorus may be as much as 5 cm. above the level at which it lies in the erect attitude.

1. The influence of gravity is on the abdominal organs as a whole, and not on the several viscera individually.

The examination of the stomach by radioscopy necessitates the presence of some contents. Of the absolutely



Figs. 9, 10, 11. Tracings from radiograms of the normal stomach partially distended with bismuth food. The duodenum and colon are outlined where shadows are present. Compare with figs. 25, 26.

There is great variety in shape and position among stomachs which can be classed as normal. Neither, within limits, indicates that the organ is pathological. The text should be consulted for the evidence which indicates the normal or abnormal condition. In every normal partially filled organ one can distinguish magenblase, cardiac sac, gastric tube, pyloric vestibule, pyloric canal, pylorus and often the duodenal bulb. There is a sharp demarcation at the pylorus between the contents in the pyloric canal and the duodenal vestibule, although, on account of overlapping of the shadows, this is not always evident.

Fig. 9. This illustration shows the relation which usually exists between the stomach and the transverse colon.

empty organ in the living, we have at present but little information, and that not at first hand.

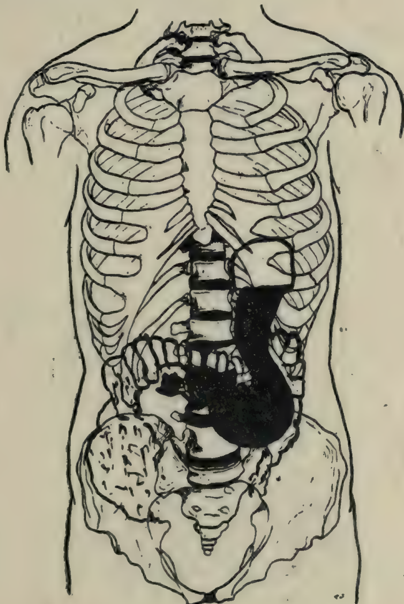


Fig. 10. Stomach pressed somewhat to the left by gas in the proximal colon. The transverse colon lies in an erratic position above the pars pylorica.

The positions of the two limbs of the stomach vary with the state of distension of the small and large intestines. The presence of gas in the hepatic flexure tends to push all parts of the stomach to the left. On the other hand, gas in the splenic flexure displaces the stomach to the right. A distended small intestine may press upward the greater curvature of the stomach, so turning the organ round an axis which passes through

the cardia and the pylorus (Schwalbe, 305). This also may occur from distension of the transverse colon with gas (117). Presumably the empty stomach is tube-like, with the exception of the fundus part of the cardiac sac

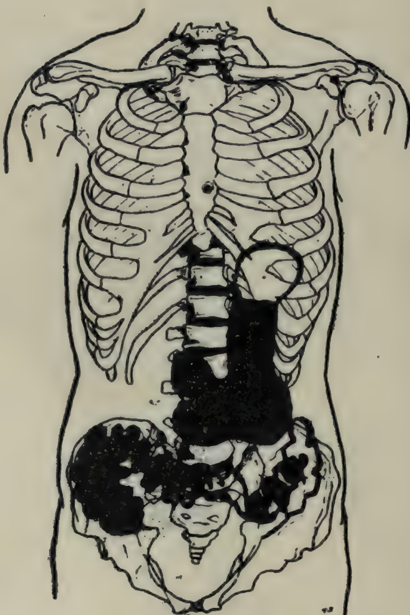


Fig. 11. The pyloric vestibule is well held up by the fibres of the Hufeisenschlinge.

(*Magenblase*), and the incisura angularis is less marked than when the organ contains food. Schwalbe states that the ventral wall is almost horizontal in certain cases, and the pyloric part may even descend somewhat toward the right. When the first portions of food are swallowed, the mass passes down the lesser curvature into the

pyloric vestibule in a continuous stream. This part of the stomach enlarges; the cardiac fundus, with its contained gas, and the pyloric vestibule, now distended with food, are connected by the narrower gastric tube. As more food enters the stomach, it passes in "blobs" through the contents of the pyloric vestibule to the lowest part of the organ. The incisura angularis

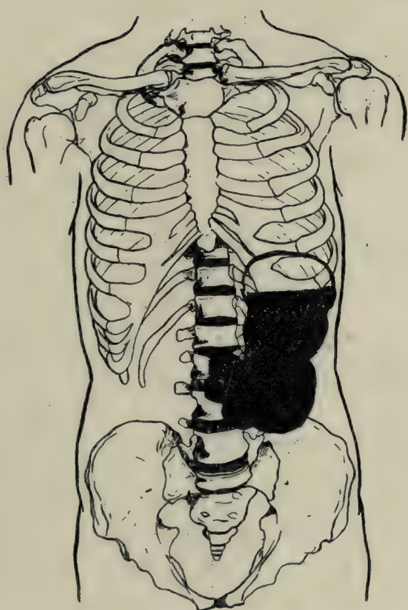


Fig. 12. Tracing from radiogram of well filled normal stomach.
Note that the pyloric vestibule has not descended to any great extent in spite of the large amount of material which it contains. The stomach distends laterally. Peristaltic waves are indicated by the indentations on the greater curvature. The vertical height of the magenblase is practically the same in the filled organ as in the empty one.

becomes more marked, and the pyloric canal, at first horizontal, becomes inclined upward and toward the right. The lowest part of the pyloric vestibule does not descend to any great extent. Waves of peristalsis commence on the greater curvature and progress towards the pylorus. As the stomach continues to fill, the ventral wall becomes more obliquely placed, and the gastric tube is gradually distended so that the longer limb of the J-shaped stomach widens laterally, but does not increase in length. The peristaltic waves commence nearer and nearer the cardiac fundus on the greater curvature. Sometimes spasm of the circular musculature of the gastric tube causes an hour-glass appearance of the organ. This spasm can, however, be massaged away in most instances in which it appears. The *Magenblase* does not decrease in vertical height as the stomach fills: it merely broadens (see figs. 9–12). The height of the transparent area of the *Magenblase* remains almost invariably the same (3·0 cm.). The ventral wall of the fully distended stomach is almost vertical.

Throughout the process of digestion the pyloric canal alters but little. As digestion proceeds, the most dependent part of the pyloric vestibule rises so that finally the pylorus itself may be the lowest part of the stomach. The first part to empty is the pyloric vestibule (corpus ventriculi), which gradually contracts again as food passes onward until the typical gastric tube is once more formed, with the air-distended cardiac fundus at the upper end and the food-filled pyloric vestibule at the lower end. Further references to the passage of food through the stomach will be made later in the chapter.

Situation and Relations of the Stomach.

The normal empty stomach is situated within the limits of the left hypochondriac and the left half of the epigastric regions. Only the pylorus and adjacent part of the pars pylorica encroach in some cases on the right epigastric region. The stomach probably does not descend below the subcostal plane. When food is present in the organ, it traverses the subcostal plane, so that the lower part (pyloric vestibule) lies in the left umbilical, or possibly the left lumbar region also, descending as low as the umbilicus when the patient is erect. Even the filled stomach is frequently found above the subcostal plane when the individual is examined in the recumbent posture.

In cases of gastroptosis the lower part of the pyloric vestibule (greater curvature) descends below the level of the umbilicus, and may even be found in the pelvis. In the cadaver the pylorus is usually found at the right side of the first lumbar vertebra (level of Addison's plane). In the normal individual the pylorus in life is shown by radioscopy to lie to the right of the second or third lumbar vertebra in the erect posture, but rises somewhat when the individual lies down. In gastroptosis the pylorus may be found even as low as the pelvis (223). A hypertonic condition of the stomach is present, in some instances of gall bladder disease and chronic appendicitis (140), and in duodenal irritation or ulcer. It is rare in gastric ulcer (140). Hypertonus of the stomach wall results in a higher position of the pylorus, and a considerable elevation of the greater curvature even in the erect position.

The cardia differs from the rest of the stomach in being comparatively stationary in position. It lies as a rule

on the left side of the body of the eleventh dorsal vertebra, but its site is liable to individual variation (see p. 43). It is lowered slightly in changing from the horizontal to the erect position, and in general visceroptosis. It lies, as a rule, about 10 cm. (4 inches) behind the ventral body wall.

The relations of the stomach may be conveniently grouped under three headings:—

(1) *Above and in front*:

Visceral surface of liver.
Ventral abdominal wall.
Fundus of gall bladder (in front of pyloric portion).
Subhepatic channel of peritoneum intervenes.

(2) *Above fundus*:

Apex of heart.
Base of left lung.
Left dome of diaphragm.
Left subphrenic pouch of peritoneum intervenes.

(3) *Below and behind*:

Organs composing the stomach bed, *i.e.*, the following from before backward:

(*a*) Transverse colon.
(*b*) Transverse mesocolon (separating stomach from duodenum and commencement of jejunum).
(*c*) Pancreas.
(*d*) Left crus of diaphragm, left adrenal, upper part of left kidney, spleen (in this order from right to left).

Middle subphrenic pouch of peritoneum (bursa omentalis) intervenes.

Apart from malignant disease, fibrous stricture, and

pyloric stenosis, which is a frequent though unrecognised cause of gastric dilatation in young adults (289), general dilatation of the stomach may be produced by mechanical obstruction of the duodenum (see p. 119) or the pylorus. In one case operated upon by Burgess, gastric distension was due solely to mechanical obstruction of the pyloric canal by pressure from a dilated gall bladder. Emptying of the gall bladder immediately relieved the distension of the stomach (44).

Adhesions, which are common in peptic ulcer and in carcinoma, may involve any of the organs mentioned in the table given above. The more usual viscera to which the stomach is adherent in such cases are the liver, gall bladder and pancreas.

The relation of the stomach to the left kidney has previously been mentioned. In certain cases, borborygmi occur in the stomach. In some instances of atonic stomach, more especially in those which possess adhesions of the pyloric vestibule to adjacent parts, Barclay has observed that by certain abdominal movements air bubbles are sucked up through the narrowed neck (gastric tube) of the stomach where it lies in relation to the left kidney, and thus the curious rattling sounds are produced (13).

Perigastric abscess may occur in any of the three peritoneal subdivisions mentioned. (For further details see p. 26.) After evacuation or drainage of the abscess, there is considerable danger of starvation of the patient if the interior of the stomach communicates with the abscess cavity into which food tends to pass from the stomach.

Reference has already been made to the stomach of the infant. Some facts regarding its relations and capacity

may be recorded here. At birth it is entirely hidden by the great development of the left lobe of the liver and by the transverse colon. This is characteristic only of the first few days of life, when the capacity of the stomach is about 35–43 cc. (1-1½ oz.). During the first and second weeks the increase in size of the stomach is very marked. By the fifteenth day the capacity is almost doubled (75–80 cc.), and part of the ventral wall of the stomach has come to lie in immediate relation to the abdominal wall. The empty organ in the infant appears from dissection to have practically the same position as in the adult. Generally speaking, the levels of the cardia and pylorus are those found in adult life. But the radiographic picture of the food-filled stomach of an infant shows the organ to be much more horizontally placed than in the adult.

At the end of the first year the capacity of the stomach is about 300 cc. (166, p. 276), but the amount of the infant's meal does not correspond with this. It would appear that some of the milk passes at once into the intestine.

As previously stated, the size and capacity of the adult stomach are so variable that reliable measurements cannot be given.

Topography and Surface Investigation of the Stomach.

In mapping out the position of the stomach on the surface of the body, due allowance must be made for sex and age, position of the patient, state of distension of the organ and other factors controlling the shape and position.

The topography of the stomach when the body is

placed horizontally on its back is given as follows:—

Cardia.

Front: Seventh left costal cartilage 2·5 cm. from the median line.

Back: 2·5 cm. to the left of the eleventh dorsal spine.

Pylorus.

Front: at or to the right of the median line on a horizontal plane midway between the suprasternal fossa and the pubic symphysis (Addison's plane, see p. 5) (2). This is three to four inches below the infrasternal notch and midway between it and the umbilicus.

When the stomach is empty, the pylorus may lie in the median line. As the organ becomes filled with food, the pylorus travels toward the right along Addison's plane. With a very distended stomach, the pylorus may be as much as 7·5 cm. to the right of the median line. Occasionally the pylorus may be found to the left of the median line (284). The causes of this have previously been outlined.

Back: At a point on the level of the first lumbar spine in, or less than 8 cm. to the right of, the median line, according to the state of distension of the organ.

Lesser Curvature. This margin of the stomach is indicated by a line joining cardia and pylorus, drawn on the abdominal wall with a downwardly directed convexity on which a point about 5 cm. to the left of the pylorus represents the site of the incisura angularis.

The Fundus of the stomach lies under the left cupola of the diaphragm. It reaches as high as the fifth intercostal space in the left lateral inguinal line. It rises a little above and behind the surface marking for the apex of the heart.

The Greater Curvature usually passes behind the inter-

section of Addison's plane with the left lateral inguinal line, a point which coincides, as a rule, with the ninth costal cartilage.

The lowest part of the greater curvature lies near the median line, and extends down to or a little above the infra-costal plane, about 5 cm. above the umbilicus.

The above described markings represent the outline of the stomach as seen in the dissecting room and give a fair indication of its delimitation in radiographic examinations when the patient is recumbent; they cannot be utilised as giving an accurate representation of the stomach when the patient is standing up.

When the stomach is examined in an adult standing erect, the pylorus and greater curvature are seen to occupy a lower level. The cardia also descends but to a less degree. The shape of the stomach more closely approximates the syphon-form.

In the erect attitude the previously given level of the cardia may be retained, but other portions of the stomach require to be outlined afresh. The following markings are those for an adult with a moderately filled stomach:

The Pylorus. Front: At or a little to the right of the median line, at the level of the infracostal plane.

Back: At or a little to the right of the median line, between the levels of the second and third lumbar vertebræ.

The pylorus in the female tends to lie at a slightly lower level than in the male.

The Lesser Curvature presents a more acute incisura angularis as the syphon-shape of the stomach becomes more marked.

The Fundus rises to the highest point of the left cupola of the diaphragm, which is 5 to 10 mm. above the inter-

section of the left lateral inguinal line with a line drawn round the body at the level of the lower end of the body of the sternum (Keith, see p. 9) (177).

The *Greater Curvature* descends as low as the umbilicus. This most dependent portion of the greater curvature is formed by the pyloric vestibule.

Of the classic methods for investigation of the stomach, inspection is far the best. In many cases the outline of the greater curvature may be seen, and occasionally waves of peristalsis passing along it can be observed even through the thickness of the abdominal wall.

If gastroptosis be present, the outline of the lesser curvature can be observed. In cases of marked gastroptosis the abdominal wall above the umbilicus may be actually scaphoid, the stomach giving the lower abdomen an abnormal prominence.

In cases of gastroptosis the lesser curvature can usually be palpated through the abdominal wall. In many individuals the normal pylorus may be palpated if care is taken to get the abdominal muscles relaxed. Percussion and auscultation are less accurate than the previously mentioned methods of investigation (143). The real size of the organ is not indicated; by the former method only the area occupied by the gas present is outlined, and this gives no information concerning the actual size of the stomach (140). The *Magenblase,* which is so obvious in the erect patient, disappears as such when the individual lies down, because the gas present in the fundus comes to lie in the cardiac part under the abdominal wall instead of under the left dome of the diaphragm.

The so-called *semilunar space of Traube* is a well-known clinical surface area, which yields a deeply

tympanitic note on percussion, and which depends for its existence upon the presence of gas in the stomach. The semilunar space is an area bounded below by the left costal margin, above by the inferior border of the left lung, to the right by the anterior margin of the left lobe of the liver, and to the left by the anterior border and anterior basal angle of the spleen. This tympanitic area is crossed about midway between its upper and lower limits by the costo-diaphragmatic line of pleural reflection. It is diminished in its upper part by pleuritic effusion, on the right by enlargement of the left lobe of the liver, and on the left by enlargement of the spleen.

In certain cases of pyloric stenosis a highly tympanitic area about 3 cm. in diameter is found over the pyloric vestibule to the right of the median line near the site of the pylorus. It is due to gaseous distension of the pars pylorica (60).

The relation of the stomach to the transverse colon can be demonstrated by filling both organs with bismuth and attempting to separate them by palpation through the abdominal wall. In the presence of dense adhesions between the two organs, such as occur in carcinoma of the body of the stomach, it is impossible to separate them by this method (99).

The Structure and Functions of the Stomach Wall.

The Serous Coat. The stomach is almost entirely covered by peritoneum. On the ventral aspect of the organ are the subhepatic channel and left subphrenic pouch of the greater sac. On the dorsal aspect is the middle subphrenic pouch (omental bursa) (lesser sac). Along the lesser curvature the gastrohepatic and gastrophrenic ligaments (lesser omentum) are attached. Along the

greater curvature the lieno-gastric and gastro-colic ligaments (great omentum) obtain attachment. In the moderately distended organ, there is a small area to the left and below the cardia which is devoid of peritoneum. Here the stomach is in direct contact with the diaphragm, and occasionally also with the upper part of the left kidney and the left adrenal gland (34).

Over the surface of the stomach the serous coat is firmly adherent to the underlying muscular tissue. Along the curvatures it is more loosely bound to the muscularis, as the great vessels supplying the stomach intervene between the two coats. When it fills with food, the organ mainly enlarges along the greater curvature, pushing its way between the approximated layers of the great omentum.

The transverse mesocolon intervenes between the stomach and the small intestine. Hence in performing gastro-enterostomy by the posterior method, one must tear through the transverse mesocolon in order to approximate the stomach and jejunum.

The Muscular Coat.

The muscular coat of the stomach is a complicated structure. Generally speaking, there are three layers, an outer longitudinal, a middle circular and an inner set of fibres. But these are very unequally developed in different areas of the stomach. The longitudinal fibres are continuous with those of the œsophagus, and are massed along the lesser and greater curvatures.[1] Those which pass over the greater curvature become thin and

1. The longitudinal fibres are massed on the dorsal and ventral aspects of the stomach alongside the lesser curvature, rather than along the lesser curvature itself.

spread out over the fundus. Between the curvatures the longitudinal fibres of the œsophagus spread out over the ventral and dorsal aspects of the stomach to form the outer oblique coat of Strecker. In the region of the gastric tube and the pyloric part, the longitudinal fibres of the greater curvature are well developed. They are a new set of muscular fibres quite independent of those which gradually tapered off on the fundus.

In the region of the pyloric canal the longitudinal fibres form a complete coat rather thicker along the greater than along the lesser curvature. A few of the more superficial fibres are usually carried on to the adjacent part of the duodenum, but soon terminate and give place to the longitudinal fibres of the duodenum itself. The greater part of the longitudinal fibres pass into the circular coat of the pyloric canal to terminate among its fibres, some, however, even reaching the submucosa. The circular fibres are most thickly massed in the pyloric part and in the gastric tube. They become much less numerous toward the cardiac sac, on which they thin out and disappear. Forssell described alternate thickening and thinning of the circular muscular coat over the region of the gastric tube, but this observation was not confirmed by Schwalbe.

There is no special thickening of circular fibres to form a middle sphincter. A longitudinal section of the pyloric sphincter frequently shows a terminal triangular mass of circular fibres at the greater and a rounded mass at the lesser curvature. The circular fibres of the pyloric sphincter are not continuous with those of the duodenum. The latter are separated from the former by a hiatus of connective tissue, which may in the adult be 3 mm. thick. The duodenal circular fibres start on a plane internal to

that of the pyloric sphincter. The circular fibres of the pyloric canal are much more numerous than those of the pyloric vestibule along the greater curvature. Hence the sudden increase in thickness is well marked at the sulcus intermedius.

Descriptions of the arrangement of the oblique fibres are frequently misleading. These fibres form a tænia on each side of the lesser curvature. The two tæniæ blend with each other round the left side of the cardiac orifice, to present a horse-shoe-shaped appearance. The tæniæ, if followed toward the pyloric part, are found to give off fibres which bend toward the greater curvature at an acute angle, and mingle with the fibres of the circular coat. At the level of the incisura angularis the tæniæ have disappeared, the whole of their fibres having merged with the circular fibres. This curious formation of the so-called oblique fibres in the region of the lesser curvature is known to veterinary surgeons as the *Hufeisenschlinge*. It forms the œsophageal groove, or *Magenstrasse*, to which reference has previously been made. It is entirely limited to the cardiac part of the stomach, *i.e.*, it is not prolonged beyond the incisura angularis. These fibres function physiologically as a second and deeper longitudinal set, although they are continuous with the circular fibres of the œsophagus, and should, according to Schwalbe, be considered morphologically part of the circular coat of the stomach.

The so-called oblique fibres of the fundus proper form a thin and sparse layer encircling it parallel to its base. The muscular coat of the cardiac sac, more especially that of the fundus proper, is rudimentary, and has little power of independent contraction. This portion of the stomach is subject to the contractions of the diaphragm

and abdominal walls as in respiration and vomiting. The neighbourhood of the incisura angularis on the lesser curvature is provided with a certain amount of elastic tissue among the muscular fibres. In some animals it forms a distinct plaque (Retzius), but as yet its function is unknown.

The above account is mainly taken from the articles by Schwalbe (305) and Cunningham (77), to which reference may be made if a fuller description is desired.

In hypertrophic stenosis of the pylorus, either or both of the longitudinal and circular coats may be affected. If the former alone is involved, there results a conical lumen with great stenosis. If the latter only is affected, a thick swelling is produced, but the lumen is not reduced (289). The condition is not a single entity. Certain instances are due to spasm of the muscular coat, as in the case recently recorded by Davis (78).

Besides the congenital and infantile forms of stenosis, there is a type found in young adults. Two cases were recently recorded by Barling, one in a man of 27, the other in a girl of 17 (17). For previous reference to this subject, see Robson and Moynihan (289).

Movements.

The following synopsis of the movements of the stomach is based on Cannon's account (48, Ch. V.).

Early in gastric digestion the greater curvature may lie several centimetres below the umbilicus when the patient is standing erect. Later it is drawn upwards, and the pylorus may even become the lowest point. The stomach is not emptied by gravity. In an active alimentary canal, gravity has not enough influence to cause the food to pass onwards. Even when the body is erect and

a large opening connects the stomach with the intestine, food will not pass through the stoma into the bowel. Nor is the stomach emptied by any form of syphon-action, as Groedel imagined (117). The muscular activity differs in the two parts of the stomach. Peristaltic waves take origin near the middle of the organ, and progress toward the pylorus. As digestion proceeds, the pyloric part alters little. The first region to decrease in size is the body of the stomach (gastric tube). As food is discharged into the intestine, the circular musculature of this middle region of the stomach contracts tonically until a tube is formed with a full cardiac sac at one end and an active pyloric vestibule at the other. The circular muscular fibres of this part (gastric tube) are collectively known to certain authors as the *transverse band* or *middle sphincter.* Shallow peristaltic waves pass along the gastric tube as the food passes into it. The tube shortens slightly, and continues its peristaltic waves until all food has entered the pyloric vestibule. The stomach is never completely divided into two by the so-called *transverse band* in the course of normal digestion, but by powerful stimulation at this point, it may be cut in two to form an hour-glass condition.

The peristaltic waves of the stomach never pass on to the duodenum. They always cease at the pyloric ring. This is what one would expect in view of the hiatus between the circular muscular fibres of the two organs. It is to be remembered that "peristalsis" in the stomach, being a wave of contraction in circular fibres only and accompanied by no advance ring of inhibition, is not a true peristalsis (diastalsis) like that of the bowel. It corresponds to the segmentation movements of the small

intestine, and is a local reflex dependent upon the presence of contents, *i.e.*, intragastric pressure. (Cf. "secondary peristalsis" of the œsophagus.) Stomachic "peristalsis" starts with the coming of food into the organ, and ceases only when all food has passed on into the duodenum. When the pylorus is closed, the peristalsis acts in thoroughly mixing the food and gastric secretion, and reducing it from a lumpy coherent mass, such as is present in the cardiac sac, into a thin fluid.

Antiperistaltic waves have been observed in the stomach, but their exact significance is not known. They are held by some to indicate pyloric obstruction. By others, however, this is denied, and they are said to occur with pyloric ulceration (99). Antiperistaltic waves start at the pylorus and progress to the incisura angularis, where they cease. In vomiting, the cardiac sac is emptied by the action of the diaphragm and abdominal muscles. In addition to peristalsis, the stomach adapts itself to the contained food so that the intragastric pressure is never raised. This pressure is much less at the cardiac end than near the pylorus, the two parts of the organ being different in function. In the adjustment of intragastric pressure, the abdominal reflex assists (see p. 11).

Variations in Tone of the Musculature.

The two properties of the gastric musculature are: (1) peristalsis; (2) tone.

In many cases peristalsis and tone are mutually dependent upon each other, and if one is absent, the other disappears. Both are controlled by the same nerve-influence. Nevertheless, clinicians find that either may

be present without the other. Some cases of very dilated atonic stomach show vigorous peristalsis in the pyloric portion. Indeed in such patients no food may reach the pyloric sphincter at all, in spite of good peristaltic waves, so long as the patient remains standing. The condition is relieved on assuming the horizontal posture.

In view of the complicated musculature of the stomach and the possibility of one set of fibres acting without the others, we have not yet a clear idea of the causation of the very different clinical pictures obtained in various pathological conditions. At any rate, stagnation of food in the stomach as the result of a primary, purely functional, weakness of the musculature probably does not exist. In such cases pyloric obstruction is stated always to be present, and it would seem that two forms of atony exist, one affecting the circular fibres alone or for the greater part, and the other involving the longitudinal fibres and those of the *Hufeisenschlinge*. Most cases present combinations in which both types of atony exist, but in which one or the other predominates. In the former type the lower part of the pyloric vestibule does not descend to any great extent, but the stomach dilates laterally, and as the circular fibres, on the integrity of whose function alone peristaltic movements depend, are atonic, peristalsis is infrequent or wanting. In the latter type the stomach maintains its narrow tubular form, which may even be accentuated, but the pyloric vestibule is greatly lowered, even into the pelvis. In such cases peristalsis may be apparently normal or even exaggerated.

In association with the latter type the pylorus may also be lowered, but this is not always the case. When it does occur, the stomach is said to present the condition of pyloroptosis. Reference to figures 13, 14 and 15 will

assist the reader to understand the distinction between the forms of atony.

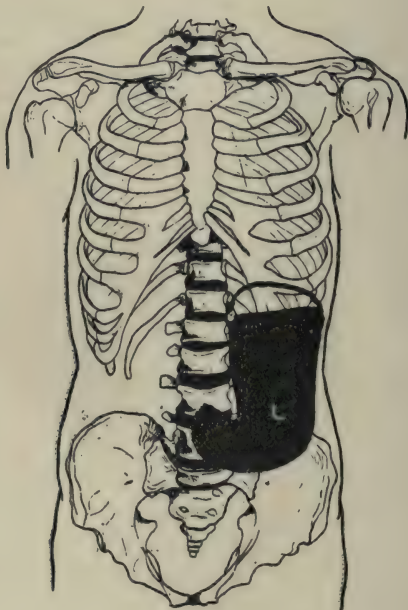


Fig. 13. Tracing from radiogram of atonic stomach.
This figure illustrates the type of organ in which the circular fibres are most affected. Observe the differences between this organ and the one illustrated in fig. 11. With lack of tone in the circular fibres peristaltic waves are not observed. Owing to the fact that the longitudinal fibres and those of the Hufeisenschlinge remain less affected than the circular fibres, the lower border of the pyloric vestibule is not dropped as in fig. 14.

Spasmodic Conditions of the Stomach.

Hypertonus of the stomach is present in cases of duodenal irritation or ulcer. The longitudinal fibres

seem most affected, and the lower border of the pyloric vestibule is drawn upwards.

A like condition is present in stenosis of the cardia, especially in cases of organic obstruction at that site. The appearance of the stomach in hunger is very similar. Hunger pain has been shown by Cannon to be caused by spasmodic contractions in a small hypertonic organ (52).

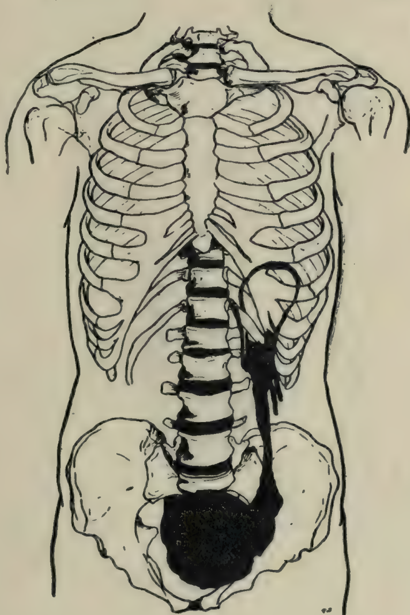


Fig. 14. Tracing from radiogram of atonic stomach.

This illustrates the type in which the longitudinal fibres and those of the Hufeisenschlinge are most affected. Inasmuch as the circular fibres remain wholly or comparatively normal in function, the stomach is not distended laterally, and also the peristaltic waves are present, for they are dependent only on the functional integrity of the circular fibres. Compare with fig. 15.

Spasm of the whole stomach is sometimes present in an acute attack of gall-stone colic or acute cholecystitis (Schlesinger, 303). Presumably it may also occur in other acute abdominal conditions, such as nephrolithiasis, pancreatitis, and appendicitis.

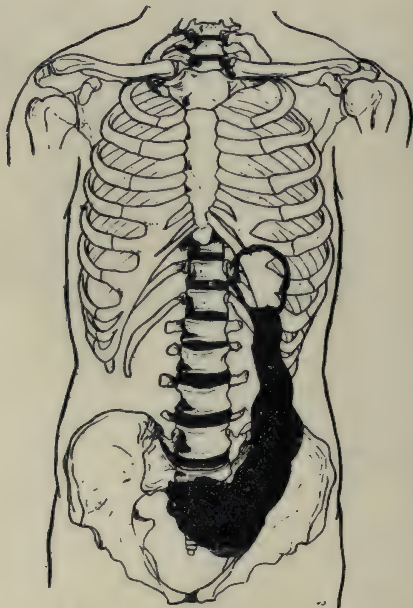


Fig. 15. Tracing from radiogram of case of pyloroptosis.
In this specimen the site of the pylorus is lowered. Compare with fig. 16.

Spasmodic contraction of the stomach in the region of the gastric tube may be massaged away (12). As a rule, it will disappear after the administration of atropine (Rieder) (see 99). But sometimes a persistent form of hour-glass stomach, which is purely spasmodic in nature

and yet uninfluenced by atropine, is found in the presence of ulcer (Faulhaber). It would seem that the circular musculature of the stomach is very easily thrown

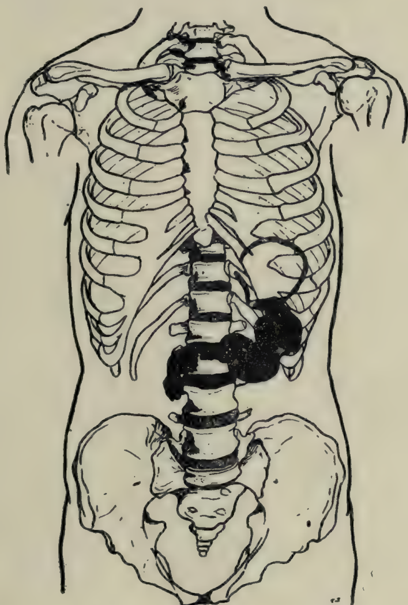


Fig. 16. Tracing from radiogram of hypertonic stomach.

Both sets of fibres are involved so that the stomach is placed high in the abdomen, well up under the diaphragm. The indentations produced by peristaltic waves are plainly shown. With contraction of the pars pylorica, there is receptive relaxation of the duodenum, the contents of which can be seen as far as the site of crossing of the colon (*i.e.*, position of Lane's first kink).

into contraction in this region. The so-called *Nischen-symptom*—the filling with bismuth of an ulcerous excavation—in association with localised hour-glass constriction is pathognomonic of ulcer (99).

Intermittent hour-glass stomachs are caused by spasms which indent the greater curvature, and which are probably due to superficial ulcerations of the mucosa or to neurosis (99). The hour-glass condition stimulated by the ulcer may become permanent (cicatricial), and remain after the ulcer has healed (12). The Röntgen picture often shows a greater degree of constriction than actually exists. That is, spasmodic constriction is present over and above the actual organic stenosis (304). Very frequently in cases of cicatricial hour-glass constriction, waves of peristalsis may be seen passing over the surface of the cardiac portion of the stomach. This is rarest in the spasmodic form.

Time occupied by the passage of Food through the Stomach.

If a bismuth meal remain in part in the stomach more than five hours after it was taken, and this in spite of good peristalsis, pyloric obstruction may be diagnosed. If the stomach be emptied in ten hours, careful dieting is probably all that is required. Should, however, the organ still present a bismuth shadow at the end of twenty-four hours, surgical interference will be necessary (12). No delay in the passage of food through the pylorus occurs in cases of duodenal ulcer (see note on p. 230).

The Submucous Coat.

The submucosa in the stomach consists of a lax connective tissue which unites the muscular coat with the mucosa. It is readily stripped off the former, but is quite adherent to the latter, with which its tissue is continuous. In it pass the vessels and nerves for the supply of the mucous membrane. Its laxity enables the

mucosa to become rugous when the muscular coat contracts. It is the site of election for the spread of carcinoma. In malignant disease of the stomach, the muscular and serous coats are found to be involved no further from the starting point of the carcinoma than is the mucosa. The submucous coat, however, may be involved a full inch beyond the furthest extension in the mucous membrane. In the pyloric region the muscular fibres are bulkier and more separated from each other than in the cardiac portion of the stomach. Hence the tissue of the submucosa penetrates farther between the fibres of the muscularis in the pars pylorica than in the rest of the organ.

The submucous coat is the chief site of the disease known as linitis plastica, to which attention has recently been directed by Lyle (220). It is of unknown cause, and characterised by a diffuse hypertrophy of the connective tissue of the submucosa, and to a less degree of the other coats also. It may occur in plaques or in more or less generalised form. The edge of the affected area fades off into normal stomach tissue, but is always sharply demarcated from duodenal tissue when it involves the region of the pyloric sphincter. This is the more remarkable when it is remembered that the submucous connective tissue of the two organs is continuous, and even forms a barrier between the circular fibres of the pyloric and duodenal muscular coats. A similar sharp clinical demarcation is found in the lymphatics of the adjoining areas (see p. 103).

The Mucous Membrane.

The mucous membrane of the stomach is thinnest in the region of the fundus, where it is only ·5 mm. in

thickness. It becomes progressively thicker from cardia to pylorus, measuring ·5 to 1·5 mm. in depth at the former situation, and 2·0 to 2·2 mm. at the latter.

Its colour is rose-pink, but becomes deeper with the congestion which occurs during the digestive period.

It consists of an epithelium of cylindrical cells, a basement membrane, a corium into which the glands extend, and a double muscularis mucosæ, the inner layer being circular, the outer longitudinal, as in œsophagus and intestine. This last separates it from the submucous coat. The tissues of the mucosa and submucosa are, however, continuous.

Rugæ are found in the mucous membrane of the contracted stomach; they disappear on distension of the organ. The rugæ are, as a rule, stellate in the cardiac portion and parallel with the long axis in the pyloric part. The mucosa differs considerably in different portions of the stomach. Many animals show a special gland formation along the lesser curvature, but this has not been described in homo. In the human stomach certain authors have described a villous appearance of the mucous membrane in the pyloric part and along the lesser curvature to the cardia. This character is not to be found in the region of the greater curvature (Ulmann, 331).

It is not necessary here to dwell on the special characters of the pyloric and fundus cells and glands. Suffice it to say that the pyloric type of gland occurs only in the pyloric canal. Some cells similar to but not identical with the parietal cells of the fundus glands are to be found in the pyloric glands and even in Brunner's glands of the duodenum (301, p. 530). The fundus type of gland with its central and parietal cells is found over

the whole extent of the stomach except where the pyloric and the cardiac types (see later) occur.

It is important to remember that Bensley and Harvey have recently shown that the acid-forming parietal cells do not produce actual hydrochloric acid, but that they secrete within themselves an alkaline forerunner of the acid, which becomes changed in reaction outside the cell (27).[1]

Adjoining the cardiac orifice of the stomach is a zone extending some 3 mm. from the cardia which presents a special form of gland known as the cardiac type, which has no pepsin secreting action, but in the pig, at any rate, produces an amylolytic ferment. (Cf. glands of lower gullet, p. 53) (301, p. 529).

The anlage of this type of gland is found in the embryonic mammalian stomach. The area over which it occurs is less in animals which have an exclusively protein diet, and greater in those whose diet is of a carbohydrate nature. Hence the cardiac glands are frequently absent in carnivora, and are well marked in truly herbivorous animals. In man the area over which this type of gland is found varies greatly in extent in different individuals. The stomach mucosa shows occasional crypts of Lieberkuhn. The site in which these are most numerous is the intermediate zone between the fundus and the pyloric area.

Whatever the mode of origin of peptic ulcer (see Bolton, 36) it is apparent that the site of disease bears

1. Just as the volume goes to press, an article has appeared by Hammett ("The source of the Hydrochloric Acid found in the Stomach," *Anat. Rec.*, Phila., 1915, vol. 9, p. 21), in which the author disputes the interpretation put by Bensley and Harvey upon their results (see *Biol. Bull.*, 1912, vol. 23, p. 225), and reaffirming on considerable evidence the previous belief that actual hydrochloric acid is produced in the parietal cells.

a very definite relation to the character of the mucous membrane of the pyloric part and the lesser curvature. Fig. 17 represents in modified form the distribution of peptic ulcer as given in Morley's recent article (245). When one considers the difficulty of defining exactly the site of ulcer at operation, and of accurately recording it in the notes, the relation of distribution of the disease to the specific characters of the mucosa is very striking.

Fig. 17. The distribution of perforated peptic ulcers according to Morley.

Note the definite relation to the lesser curvature, especially of the pars pylorica and to the duodenal vestibule.

Dots represent perforations on ventral surface; circles, perforations on dorsal aspect.

Other facts which indicate physiological differences between the mucous membrane of the several parts of the stomach are the chemical stimulation of gastric juice and the action of acid in the stomach on the pyloric orifice. These mechanisms are operated from the mucosa of the pars pylorica only (48, Ch. VI). The action of

acid in the cardiac portion closing the cardia has already been discussed (see p. 57).

The Arteries of the Stomach.

The arterial supply of the stomach comes from the cœliac trunk. This short wide vessel lies behind the omental bursa, and runs forward for 12 mm. between the caudate lobe of the liver above and the upper border of the pancreas and the splenic vein below. It terminates by dividing into the left gastric, the hepatic and the splenic. The left gastric (coronary) artery runs upward and to the left behind the omental bursa, and passing forward in the left gastro-pancreatic fold, reaches the lesser curvature adjacent to the cardia. It courses along the lesser curvature close to the stomach wall, and anastomoses with the right gastric (pyloric) branch of the hepatic artery. It gives branches to the lower gullet and to both surfaces of the stomach. Many of these pierce the circular musculature of the *Magenstrasse* and form a plexus in the submucosa.

In 15 per cent. of cases a branch runs also to the left lobe of the liver (286). In such cases ligature of the left gastric artery in partial resection of the stomach would result in necrosis of the liver area supplied by it.

The hepatic artery runs along the upper border of the head of the pancreas and between the layers of the right gastro-pancreatic fold of peritoneum to reach the first part of the duodenum. From here it passes upward between the layers of the hepato-duodenal ligament to reach the liver. Its branches to the stomach are the right gastric and the gastro-duodenal vessels.

The right gastric artery arises from the hepatic trunk in the gastro-hepatic ligament above the pylorus, to which it passes, whence it courses to the left, supplying

both sides of the pyloric part of the stomach, and anastomosing with the left gastric artery in the region of the incisura angularis. Like the left gastric vessel, it is closely applied to the stomach wall.

The gastro-duodenal artery descends behind the first part of the duodenum, on the under aspect of which it divides into the right gastro-epiploic and superior pancreatico-duodenal vessels.

It frequently happens that this subdivision is closely related to the pyloric canal.

The right gastro-epiploic artery passes to the left behind the first part of the duodenum and above the head of the pancreas to reach the gastro-colic ligament (part of great omentum) between the layers of which it runs parallel to but some distance from the greater curvature (unless the stomach is full) to supply the pyloric canal and vestibule with branches. It anastomoses with the left gastro-epiploic vessel near the junction of the gastric tube with the pyloric vestibule.

The splenic artery, which is large and tortuous, passes to the left, behind the omental bursa along the upper border of the pancreas. It reaches the hilum of the spleen by running between the layers of the lieno-renal ligament, and its branches to the stomach pass onward between the layers of the gastro-splenic ligament (part of great omentum). These are the vasa brevia, which supply the fundus proper and adjacent parts of the cardiac sac, and the left gastro-epiploic, which gives off branches to the gastric tube and adjacent part of the cardiac sac. Like the right gastro-epiploic artery, the latter lies some distance from the greater curvature when the stomach is empty.

The vessels from which hæmorrhage occurs in gastric

ulcer are the two gastrics, the splenic and the superior pancreatico-duodenal (21). These are the arteries which present a close relation to the stomach wall whether the organ be empty or distended. As previously mentioned, the stomach dilates by burrowing between the folds of the gastro-colic and gastro-splenic ligaments. Hence the gastro-epiploic vessels lie in these ligaments at some distance from the greater curvature of the empty stomach, and are practically never ulcerated. The left and right gastric vessels are those from which hæmorrhage most frequently occurs. The splenic artery is exposed by ulcers of the dorsal wall laying bare the pancreas.

The superior pancreatico-duodenal artery is invaded where it lies in contact with the dorsal surface of the pyloric canal.

Only the terminal vessels of the mucosa are end arteries. The submucous plexus allows free communication between the different arterial channels (82).

The Veins of the Stomach.

The veins of the stomach follow the course already described for the corresponding arteries, but their termination is different in some cases. The short gastric and the left gastro-epiploic veins terminate in the splenic trunk. The right gastro-epiploic ends in the superior mesenteric vein. This and the splenic by their union form the portal vein. Into the portal vein itself is poured the blood from the left gastric or coronary and the right gastric veins.

Bleeding from the veins of the stomach rarely occurs in gastric ulcer, as the vessels readily thrombose. On the other hand, venous hæmorrhage into the stomach does take place in the congested state of the portal

system consequent on the obstruction to the portal vein found in cirrhosis of the liver. In these cases the bleeding results from the bursting of swollen anastomotic veins at the cardiac orifice. These small vessels form communications between the œsophageal veins which pour their blood into the systemic circulation through the azygos veins, and the gastric vessels which drain into the portal system. Hæmorrhage from the veins of the stomach also occurs occasionally after abdominal operations and occasions post-operative hæmatemesis. The bleeding is said by some to result from a congested state of the mucous membrane produced by thrombosis of the gastro-epiploic veins following on ligature or rough handling of the omentum. The gastro-epiploic veins and arteries send branches into the greater omentum as well as to the stomach. According to von Eiselsberg, thrombosis of the omental arteries proceeds to involve the gastro-epiploic arteries just as happens in the case of the veins (90).

But all investigators do not agree that ligature of omental blood vessels causes bleeding from the mucosa. Engelhardt and Neck proved that bleeding certainly does not occur in all cases. Owing to the submucous arterial and venous plexuses the blocking of one or several branches cannot cause any considerable disturbance in circulation since numerous collateral branches exist (95).

A fact of considerable significance concerning the veins of the embryonic stomach has been discussed by Broman. This author describes branches of the ductus venosus to the stomach in embryos of 5 to 16 mm. Obviously the ductus venosus would be carrying arterial blood. Hence the stomach, which at this stage is rapidly

developing its characteristic appearance, would obtain the necessary pure blood in contradistinction to the greater part of the abdomen, which receives only the relatively impure blood from the abdominal aorta.

One little vessel of some practical importance, when it exists, is the pyloric vein, described by Mayo and by Moynihan (248). It joins the veins of the greater or lesser curvature and runs over or close to the pyloric sphincter. Thus it may be used to define the pyloro-duodenal junction, but does not do so accurately.

The Lymphatics of the Stomach.

This subject has been discussed in great detail by various authors (see 160), but for practical purposes the description can be greatly simplified. The lymphatic vessels of the stomach drain into the coronary, pyloric, and splenic groups of nodes.

The coronary group lies along the lesser curvature and forms a chain of nodes continuous with those in the posterior mediastinum along the lower gullet, whose lymphatic vessels form a common plexus with those of the stomach.

The coronary group drains the cardiac part of the lesser curvature and adjacent portions of the ventral and dorsal surfaces.

The pyloric group of nodes is arranged in front, behind and below the pyloric canal and vestibule, and drains the whole of the pyloric portion of the stomach. According to many observers the lymphatic plexus of the pyloric part of the stomach is not anatomically continuous with that of the first part of the duodenum. Hence carcinoma of the pyloric region is stated not to spread distally into the duodenum, but always toward

the body of the stomach. Most considered that there is *eine scharfe lymphscheide* between the pyloric canal and the duodenum (247). Lately Comolli has reinvestigated the subject and takes the view that the lymphatic plexuses of the pyloric canal and duodenum are continuous. He quotes the statement of Borrmann that in 20 out of 65 cases of carcinoma of the pyloric region, there was extension to the duodenum by both submucous and subserous lymph tracts (69).

No lymph nodes are present in the gastro-splenic ligament. All the vessels of the fundus proper and adjacent part of the cardiac sac drain into the splenic group of nodes situated along the splenic artery.

As in other parts of the gastro-intestinal tract, the lymphatic vessels of the stomach are arranged at right angles to the curvatures so that when injected with Prussian blue or some other dye the colour is observed to flow round the gut in a circular direction more readily than in the longitudinal. Following on this lymphatic distribution, carcinoma of the stomach tends to form an annular growth in the wall of the organ.

The reason for the rarity of the spread of pyloric carcinoma to the duodenum, as is observed by the majority of investigators, is probably explained by the fact that the disease blocks the smallest lymphatics and tracks along those of medium size (see Sampson Handley (24)).

There is little or no *clinical*[1] anastomosis between the lymphatics of the fundus and those of the rest of the

1. Because the smallest lymphatic vessels are choked by the growth and thus prevent its extension along them, the lymphatics of one area, though anatomically continuous with those of adjoining districts, may yet be clinically isolated, there being no medium-sized vessels along which the carcinoma may spread.

organ. Consequently, carcinoma of the fundus has a better post-operative prognosis than malignant disease elsewhere in the stomach. For this reason the fundus and adjacent parts of the cardiac sac are together known as the *isolated area*. The amount of gastric wall which it is necessary to extirpate in carcinoma of the fundus is delimited toward the right by a perpendicular (Hartmann-Mikulicz) line to the greater curvature meeting the lesser curvature immediately to the right of the cardiac orifice. The intersection of the perpendicular with the greater curvature is termed Hartmann's point (126). It is to be noted that this line is drawn on the atonic organ as seen in the operating theatre. This line may also be utilised in pyloric carcinoma. Thus the fundus and two-thirds of the greater curvature are free from lymphatic involvement in cancer of the pylorus (231).

As inflammation does not occur in the mucous membrane without the other coats of the stomach also being involved, the presence of an ulcer can always be detected by inspection of the peritoneal coat (248). Indeed an enlarged and inflamed "sentinel" lymphatic node is frequently present in consequence of an ulcer in the mucosa.

The Nerves of the Stomach.

The nerves of the stomach originate from the vagi and the sixth, seventh, eighth, and ninth dorsal segments of the spinal cord. The latter group are composed of sympathetic fibres which reach the stomach through the splanchnic nerves. Of these the sixth dorsal segment supplies the cardiac orifice, while the pylorus derives its nerve supply from the ninth dorsal segment. Referred

pain in the abdominal wall is therefore felt in the area supplied by the cutaneous nerves from these same dorsal segments. Ulcer near the cardia produces referred pain in the infra-sternal region, while ulcer of the pylorus is associated with referred pain just above the umbilicus. But it is to be noted that Ducceschi observed that the afferent fibres of each splanchnic nerve are connected through filaments from the cœliac plexus with the entire surface of the stomach (84, p. 525).

In the stomach wall itself there exist two nerve plexuses, one in the submucous coat known as Meisner's, and the other in the muscular coat. This latter is called Auerbach's plexus. These plexuses are connected with splanchnic nerves and are jointly responsible for the mechanism known as the local or as Cannon has named it, the *myenteric* reflex (48). By this term is meant the intrinsic response of the gut to stimulation by its contents to ensure the orderly progression of the said contents. The response consists of a contraction immediately in front of and a relaxation beyond the point of stimulation. The relaxation may be marked or may be very slight. It is probable, however, that the myenteric reflex does not control the rhythmic waves of contraction in the stomach, usually known as "peristalsis" (48, p. 195). The endings of the vagus fibres in the stomach have not been traced. They probably terminate in association with outlying nerve cells in the gastric wall which have no connection with the myenteric (Auerbach's) plexus (48, p. 198).

Rubinato at any rate has shown two distinctly different types of nerve cells in the wall of the stomach (297). A clearer description, which, however, does not harmonise with that of Rubinato, is given by Kuntz of the nerve

cells and fibres in the stomach wall (195). The function of the vagus is that of maintaining a state of tone in the gastric musculature. The gastric contents may be said always to exert a stretching effect on the stomach wall. The vagus adapts the size of the organ to the amount of food taken. Only if this tone is present are peristaltic waves stimulated. For tone and peristalsis are mutually dependent upon each other. It is obvious, however, from preceding clinical statements (p. 88) that the tone spoken of here refers to the circular muscular fibres and not necessarily to the longitudinal musculature, or the Hufeisenschlinge. The vagi are also concerned in the production of a psychic tone similar to the psychic secretion (48, p. 240). The section of one vagus has no effect upon the state of the stomach because of the interweaving of the fibres on their way down the œsophagus (300, p. 52).

If both vagi are cut, the circular muscular tone and peristalsis are inhibited for a time. Ultimately the stomach recovers both tone and peristalsis. This restoration occurs much more quickly if the splanchnic nerves also are severed (48, p. 201). For these act as inhibitory nerves to the gut, stimulation of them causing diminished tone and weakened rhythmic contractions.

The recovery of tone and peristalsis by the gastric wall after section of the vagi is most important clinically, for in Sauerbruch's operation for resection of the cardia it is necessary to sever both vagi (300, p. 89). Indeed they may already be damaged by the presence of local malignant disease.

Another important fact in the stomach mechanism is that neither tone of circular fibres nor peristalsis is necessarily dependent ultimately upon the integrity of

the myenteric reflex any more than they are on the presence of vagus influence. Cannon cut rings through both muscular coats, thus severing Auerbach's plexus. In one case six rings were cut between the cardiac end of the stomach and the pylorus, and after three weeks the waves were seen passing with perfect regularity as in the normal stomach (48, p. 193).

But it must not be thought that the rhythmic movements of gastric peristalsis are necessarily of myogenic origin. Cannon gives an excellent summary of the work of Magnus refuting the evidence which Bayliss and Starling brought forward in favour of the myogenic theory (48, pp. 180, 181). More recently Kuntz has presented anatomical evidence to show that the local mechanism is that of an *axone* reflex. Kuntz's work suggests that, however close together the circular incisions be made through the muscular coat, it is impossible to preclude the possibility of axone reflex. The afferent impulse caused by the contact of food with the mucous membrane results in a contraction of the musculature in the immediate neighbourhood (195). Hence the rhythmic wave is started and as the food is necessarily pushed onward, it stimulates a similar contraction as it passes with the production of the so-called peristaltic movement. The important relation to partial gastrectomy of this mode of production of peristalsis in the stomach is obvious.

Kirschner and Mangold found the gastric functions perfectly restored in dogs after circular resection of the stomach. The tone of the pyloric sphincter, the rhythmic opening and closing of the pylorus while the stomach is emptying, the rise of intra-gastric pressure in the pyloric vestibule and the rhythm and character

of the contractions of this portion of the stomach, all recover to a normal degree. The functional co-ordination of the pyloric sphincter and of the wall of the pyloric vestibule, and the reflex response of the pars pylorica to chemical stimulation from the duodenal mucosa also recover (190).

It would seem, however, that absence of tension by contents may result in atony. Wilms has asserted his belief that in cases where the stomach is divided and both ends are closed by suture, there is resulting atony of the excluded pyloric portion (348).

With regard to the cardiac and pyloric sphincters it may be said that although they are affected by local conditions, such as acidity, they are also controlled by the central nervous system. Stimulation of the vagus causes relaxation of the cardiac sphincter with subsequent increase in tone (see p. 56). But stimulation of the vagus as a rule produces closure of the pyloric sphincter (48, p. 207).

The splanchnic nerves act in the opposite way, closing the cardiac orifice and relaxing the pylorus in some animals. But the effect of stimulation of the splanchnics is not so uniform as that of vagus stimulation (48, p. 207) (see p. 56).

That the same mechanism which opens the cardia should close the pylorus is of importance in vomiting. It is interesting to observe that there is a receptive relaxation of the cardiac sac dependent upon the stimulation of the vagus nerve. This occurs with each swallow. The œsophagus contracts pressing the food into the stomach, while at the same time there is temporary relaxation of the cardiac sphincter and of the cardiac sac. Immediately the bolus has entered the

stomach, the cardia closes and the intra-gastric pressure increases. The food lies in the lower part of the cardiac sac at the commencement of the gastric tube. The slight increase in tone of the cardiac sac produces the tension necessary for the initiation of the peristaltic wave, which carries the food along the gastric tube to the pyloric vestibule (see Cannon, 48, pp. 198, 201).

Sensory impulses from the stomach are probably conveyed by the vagi only (Miller, 238). Kast and Meltzer (173), and recently Miller, have cast doubt upon the insensibility of the alimentary canal to pain. But this is not borne out by clinical observations. According to Hertz (138), the organ is insentitive to temperature, to tactile and cutting sensations.

Alcohol is said to excite a burning sensation, which is the cause of the discomfort in heartburn, but this sensation may equally well be caused in the lower gullet by leakage through the cardia, and not in the stomach itself (147). Other chemical stimulation, as by hydrochloric or an organic acid, produces no effect on the normal stomach. The presence of even weak hydrochloric acid gives pain when introduced into the stomach of patients who are suffering from gastric ulcer (37).

Distension of the organ produces a sensation of fulness.

Gastralgia is due to irregular spasmodic contractions of the muscular wall. As these are increased by carbonised water, it is probable that cramp-like pains in the stomach are stimulated by the presence of gas, especially of carbon dioxide. They are relieved by eructation. An instance of painful spasm is given by hunger pain, which is produced by contractions in a nearly empty

stomach. Hunger pain can be relieved momentarily by swallowing. This is explained by the temporary inhibition of gastric contraction through vagus influence (48, p. 204).

Pain in cases of gastric ulcer may be due to one of two causes. It may be local tenderness which is the result of local peritonitis, or referred pain caused by stimulation of the spinal fibres to the abdominal wall. The site of the referred pain is said by some writers to bear in its distribution a constant relation to the site of the ulcer. Such a table is given by Mayo Robson and Moynihan (289, Ch. VII), but as it is doubtful if such a relation can be substantiated, the table has not been included in this account.

CHAPTER VII.

The Duodenum.

The duodenum is that part of the alimentary canal which forms the commencement of the small intestine, and into which open the bile and pancreatic ducts. It differs from the remainder of the small intestine in that for the greater part of its extent it is bound down by peritoneum to the dorsal abdominal wall.

Unlike its termination, the site of its commencement has always been definitely settled and is marked by the pylorus. If the sphincter be relaxed and thus not palpable during operation, the pyloric vein already mentioned (p. 103) may indicate approximately its position. The termination of the duodenum has been variously defined from time to time. At present we regard it as occurring in a more or less well-marked elbow of the gut at or about where the mesentery of the small intestine commences, a distance of some 30 cm. from the pylorus. It is quite easily discerned in the operating room during an abdominal operation, for the muscle of Treitz can be traced to it from the dorsal abdominal wall. But at one time the junction of duodenum and jejunum was held to occur at the site where the superior mesenteric vessels cross what is now termed the third part of the duodenum, and it was the distance measured in finger breadths along the gut, between the pylorus and this situation, which gave rise to the name duodenum. In the early embryo there is no flexure between duodenum and jejunum, and for this reason the term duodenum, even in the adult, has been

limited to the segment of bowel between the pylorus and the opening of the common bile duct. In the sixth week of fœtal life, however, the duodenum assumes a curved form, and by the third month, it has the same disposition as at birth (166). Quite recently Villemin has denied the duodeno-jejunal junction to be the distal limit of the duodenum. He states that the real termination in the adult is located at a position some inches higher. This site is identified by the presence of a valvule composed mostly of mucous membrane, but into which also the circular muscular coat enters, by the cessation of Brunner's glands and by the attachment of the muscle of Treitz (334). But these features are not so distinct in the fœtus or in lower animals.

In the fœtus and infant the duodenum is ring-shaped; indeed even in the adult this type frequently occurs. Jonnesco says that as a rule the ring-type is observed only up to the age of seven. In the adult the duodenum commonly is U-shaped, though, as one would expect, there are intermediate conditions between the ring and U forms (10). According to Dwight, the types just mentioned are more characteristic of the male. In the female a V-shaped duodenum quite commonly occurs, and the most dependent part of the duodenum tends to lie lower in the abdomen than it does in the male. Jonnesco states that the horizontal part of the U-shaped duodenum lies as low as the fourth lumbar vertebra, and that the V-shaped organ reaches the fifth (*Progrès médical*, 1889); and these observations were confirmed by Dwight (85).

In the cadaver the precise relation of the duodenum to the jejunum, at the flexure, varies. Bishop Harman differentiated the following groups:—

(1) A wide curve downward, forward and toward the left.
(2) A sharp curve disposed in the same manner.
(3) A sharp curve directly forward and downward along the line of the ascending portion of the duodenum.
(4) A slight curve, the jejunum passing at once to the right.

In all cases, Harman adds, the position was fixed and not subject to the movements of the intestines (125). But owing to the difficulty of tracing on the fluoroscopic screen a bismuth mixture as it passes through the flexure, it is impossible at present to record the condition during life. Such evidence as we have is distinctly against there being any impediment to the passage of food by a sharp curve or kink at this site. Moreover, in the cadaver the duodeno-jejunal flexure tends to rise somewhat higher in the abdomen than in the standing living individual, and also there is post-mortem contraction and fixation, which tend to exaggerate the sharpness of the normal curve.

The duodenal-jejunal flexure is not always free, that is, the jejunum may not invariably have a mesentery quite to its commencement. It may be bound down to the dorsal abdominal wall for a short distance beyond the flexure (125).

In the formalin-hardened cadaver, which has been injected while lying on its back, the first part of the duodenum commences in the middle line, or within three or four cm. to the right of the middle line, opposite the lower part of the first lumbar vertebra, and passes backward to the right and slightly upward to its junction with the second part in the region of the neck of the

gall bladder, and at the level of the first lumbar vertebra. This portion of the duodenum is anchored by a continuation of the lesser omentum. Then bending on itself the bowel lies almost vertically on the right side of the bodies of the second, third, and fourth, and it may be the fifth, lumbar vertebræ. This is the second part. The third part then crosses the front of the great vessels upon the vertebral column, and the fourth part ascends toward the left and passes obliquely backward and to the left to terminate at the duodeno-jejunal junction, which lies about three or four cm. to the left of the middle line, at the level of the disc between the first and second lumbar vertebræ. It is to be observed that while Jonnesco, Treves (329) and Hartmann use the terms third and fourth parts of the duodenum, these are frequently grouped together in English text-books as the third portion.

It has already been mentioned that, in many individuals, the firmly contracted pylorus can be palpated through the abdominal wall.

The duodenum, as mapped out on the abdomen of the cadaver, does not altogether correspond to its surface topography in the living. One must remember that in the cadaver all parts of the organ, but more especially the commencement and termination, tend to lie at a higher level than in the normal living adult in the standing posture. The right lateral inguinal, the transpyloric and the intertubercular lines are required for the topographic marking. In the cadaver the first part lies on the transpyloric plane, the junction between first and second portions corresponds to the intersection of transpyloric and right lateral inguinal lines, the second part lies just medial to the lateral inguinal line, the third

part crosses the median plane at or about the level of the intertubercular plane (according to certain authors the crossing is somewhat higher than this (2) (100)), and the fourth part passes obliquely upward and to the left to end at the duodeno-jejunal junction about three or four cm. to the left of the median plane on the transpyloric line. Hence the summit of the iliac crest, if that can be palpated, corresponds roughly, as Addison points out, to the lowest limit of the duodenum (2). The foregoing outline indicates for the third part of the organ a lower level than that given by Addison. Addison states that it crosses the middle line about one inch above the umbilicus, a situation rather too high than too low, and one which is indicated by the relation to the umbilicus, which is itself somewhat variable in its position relative to the vertebral column (see p. 2). The differences between the situation of the several parts of the organ in the cadaver and in the living will be obvious by reference to the radiographic appearance (p. 129).

Variations in the position of the duodenum may be due to the presence of a mesentery or may be one feature of a general abnormal disposition of the abdominal organs. From time to time such accounts have been published in the *Journal of Anatomy and Physiology*, and a very marked instance has been recorded by Riechelmann (283). Sometimes, as in Chiene's case, the duodenum passes into the jejunum to the right of the median line (59). This variation must not be confused with the appearance noted by Jordan in certain cases of so-called Lane's kink (see p. 131).

The distance of the duodenum from the upper incisor teeth varies according to the individual. Gross has been able to insert a duodenal tube 150 to 200 cm. along the

alimentary canal. By pushing it to the 70 cm. mark and waiting until the pylorus has allowed it to pass, or rather has carried it into the duodenum, a free flow of yellowish cloudy fluid of acid reaction is obtained. This is soon replaced by a clear golden yellow or greenish fluorescent alkaline fluid, which latter is supposed to be true duodenal juice (119). By the same method, Gross proposes to inhibit bacterial proliferation by insufflation of oxygen (120). Allard recommends Einhorn's test in duodenal ulcer. The somewhat crude technique of this test is carried out by inducing the patient to swallow a string. When drawn up again, brown discolouration from blood on the string at a distance of from 55 to 65 cm. from the incisor teeth is said to indicate the presence of a duodenal ulcer (4). Transduodenal lavage is recently recommended by Jutte as treatment for intestinal auto-intoxication (170), but the diagnosis of intoxication is based on the presence of indican in the urine, and as a test of intestinal intoxication, indicanuria is fallacious (see 271).

In the accounts given by English text-books the relations of the duodenum to surrounding viscera are frequently incomplete. For this reason the description given by Jonnesco is tabulated below (166):—

FIRST PART.

Above. Liver at right part of hilum.
Below. Neck of pancreas.
Ventral. Visceral surface of liver.
Body of gall bladder.
Dorsal. Neck of pancreas.
Hepatic pedicle (*i.e.,* portal vein, hepatic artery with its gastro-duodenal branch, union of cystic and hepatic ducts to form common bile duct).

SECOND PART.

Ventral. Fundus of gall bladder.
Right extremity of transverse colon.
Right colic vessels.
Small intestine.

Dorsal. Renal and genital vessels.
Right kidney, pelvis and ureter.
Psoas and quadratus lumborum.

Right. Right lobe of liver.
Ascending colon.
Right kidney.

Left. Greater curvature of stomach and pyloric canal.
Head of pancreas.
Common bile and pancreatic ducts.
Inferior vena cava.
Vertebral column.

THIRD PART.

Above. Head of pancreas.

Ventral. Root of mesentery with superior mesenteric vessels.
Small intestine.
Pyloric vestibule.

Dorsal. Inferior vena cava.
Abdominal aorta or its bifurcation.
Origin of inferior mesenteric artery.

FOURTH PART.

Ventral. Small intestine.
Pyloric vestibule.

Dorsal. Left renal and genital vessels.
Lumbar part of diaphragm and psoas separated from the duodenum by the ureter.

Pelvis of ureter and hilum of right kidney. (This occasionally in adult, but always in child up to the age of three or four.)

Right. Aorta.
Root of mesentery.
Head of pancreas.

Left. Left kidney.
Left colic artery.
Inferior mesenteric vein.

In the infant the kidneys fill up the paravertebral hollows, and therefore the loop of the duodenum lies on the hila of the two kidneys and on the crura of the diaphragm with the abdominal vessels between them. In the adult, however, the kidneys, relatively reduced in size, sink back into the paravertebral hollows, and the duodenum tends to follow them. Hence the more vertical parts of the duodenal loop are recessed in the abdomen to a plane posterior to that of the third or horizontal part.

The third portion of the duodenum lies in the angle between the aorta dorsally and the superior mesenteric artery ventrally. Besides being bound down by peritoneum, this relation to the vessels makes it the least movable part of the duodenum. Thus in abdominal injuries, if the organ is ruptured, it is the third part which usually suffers. Further, this relation may be the cause, in some cases at least, of acute post-operative dilatation of the stomach. In patients, who at operation have the small intestine loaded with contents, it is supposed that the heavy terminal coils of intestine may drag upon the root of the mesentery, the smooth muscle fibres of which are in an atonic state. By such action

the third part of the duodenum suffers mechanical constriction between the aorta and superior mesenteric vessels. The equally atonic stomach and duodenum are unable to force their contents past the obstruction and rapid dilatation results. Part of the treatment of this condition is directed to the relief of such obstruction by raising the foot of the bed and so putting an end to the tension on the mesentery (248). Kelling notes that such a type of obstruction occurs sometimes after a simple cholecystotomy, and he suggests that local peritonitis or perhaps even tight abdominal bandaging may be factors in its causation. He observes also that in certain cases no bile but only food and blood-stained fluid are found in the stomach. In these instances, he believes that the obstruction is produced by the pressure of the distended first part of the duodenum against the ventral wall of the second portion (188).

Richardson recently had the opportunity of watching a stomach dilate on the operating table before his eyes. It seemed to be obstructed at cardia and pylorus, and as the organ distended, it rolled upward so that the greater curvature came forward. No distension of the duodenum was noted. The stomach wall contracted firmly when the gas was allowed to escape through a stomach tube passed through the mouth (281).

Acute obstruction of the duodenum is a very fatal condition, the symptoms of which have been studied by several investigators. They have been induced lately by Whipple and his co-workers in dogs, and by Bunting in rabbits, by isolating a loop of duodenum. This is effected by ligaturing the duodenum just beyond the entrance of the common bile duct, and immediately distal to the duodeno-jejunal junction and then performing a

posterior gastro-enterostomy. If the duodenal loop is excised or drained, the symptoms are absent or much less marked. The activity of the mucosa and contained bacteria form some very toxic substance, which is apparently absorbed directly into the blood (342). Hence it would seem that the rapidly fatal character of high intestinal obstruction in man is not due merely to the mechanical occlusion.

Chronic obstruction with duodenal stasis has been much studied of late by Lane and Jordan. The organ is said to become distended most in the first part, but this *bulbus* is apparent radiographically in normal cases (see p. 125). There is said to be a kink at the duodeno-jejunal junction, but this has never been fully substantiated. The bismuth shadow, in cases of duodenal stasis, is said by Jordan to lie entirely to the right of the middle line (168). Dwight believed that in many cases the fourth part of the empty duodenum lies to the right of the vertebral column in the adult, and that in such cases it is only displaced to the left by distension. In the infant Dwight said the fourth part is usually to the right of the column (85). Hartmann (*Bull. Soc. Anat.*, Paris, 1889), on the other hand, wrote that the terminal part of the duodenum is only exceptionally to the right of the column. Even if Dwight's view be taken, it could not account for the condition observed by Jordan in the obviously distended duodenum. It is plain that Jordan has not considered the possible cessation of the shadow at the point of crossing of the gut by the superior mesenteric vessels.

In their relation to the peritoneum, the several parts of the duodenum differ markedly from each other. The first part is entirely surrounded by peritoneum, as is the

stomach. Indeed, extensions of both gastro-hepatic and greater omenta are carried along continuously from the stomach on to the first part of the duodenum. Further, in one subject out of four the gastro-hepatic omentum extends to the gall bladder, so that from this organ to the duodenum there is, in such cases, a peritoneal band, which is called the cysto-duodenal ligament (166). Sometimes this is continuous over the ventral face of the duodenum with the greater omentum, and thus the duodenum is bound also to the transverse colon by the so-called duodeno-colic ligament. Previous to the passage of a gall stone into the duodenum by direct ulceration, many adhesions are formed between gall bladder and duodenum, with the cysto-duodenal ligament as a nucleus.

The second part of the duodenum is bound down to the dorsal abdominal wall by peritoneum. Indeed, even the ventral aspect of the organ is devoid of a peritoneal coat where the transverse colon crosses it. The peritoneum passes directly from the duodenum on to the ventral aspect of the right kidney. Kocher's method of mobilising the duodenum in cases in which it is desirable to remove a gall stone from the common duct or Vater's ampulla from behind, consists in incising the peritoneum over the right kidney and turning the bowel, freed in this manner, forward and to the left (191). As the first and second parts of the duodenum form part of the dorsal wall of the subhepatic channel (see p. 28), it follows that perforation of the ventral wall of the first part, in duodenal ulcer, will result in the passage of contents to the right or left, but more usually the drainage is to the right into the peritoneal pocket to the lateral side of the right kidney, in other words, into the area known

as the right kidney pouch of Rutherford Morison (p. 22) (312). As the appendix may also drain into the pouch, local tenderness may occur over this area either from appendicular abscess or from a perforated duodenal ulcer (248).

Here one may observe that it is the peritoneal coat which is most important in preventing sutures from tearing out of the bowel wall. Where the gut is not covered by peritoneum, the wall is friable and does not hold sutures. Consequently when it is necessary in cases of extensive resection of the pylorus to mobilise the second part of the duodenum and to divide it rather than the first part, the dorsal wall of the gut which is devoid of peritoneum requires special care in suturing. Krogius advises that after ligature or suture that part of the duodenum from which the peritoneal coat is absent should be depressed into the intestinal lumen and buried by a continuous Lembert suture uniting the adjacent margins of the peritoneal defect (193).

The third part of the duodenum, like the second, is devoid of a mesentery and, further, it is also uncovered by peritoneum where it is crossed by the root of the mesentery with the included superior mesenteric vessels. Reference has already (p. 119) been made to the connection of this with duodenal stasis and injury.

Between the fourth part of the duodenum and the hilum of the left kidney in the adult, there is a vertical fold of peritoneum raised by the left colic artery, a branch of the inferior mesenteric artery, and the inferior mesenteric vein, a tributary of the splenic. Together these vessels form the vascular arch of Treitz. The terminal part of the duodenum and the vascular arch, with the splenic vein above and the commencement of

the left colic artery below, form the ramparts, as it were, of a peritoneal fossa. The peritoneal folds do not, however, always lie over the structure which probably was the original cause of the fold. But any one of these folds may form a pocket of peritoneum into which an internal hernia may find its way (251). They are superior, inferior, right and left duodenal fossæ respectively.

The duodenum has a greater calibre than any succeed-

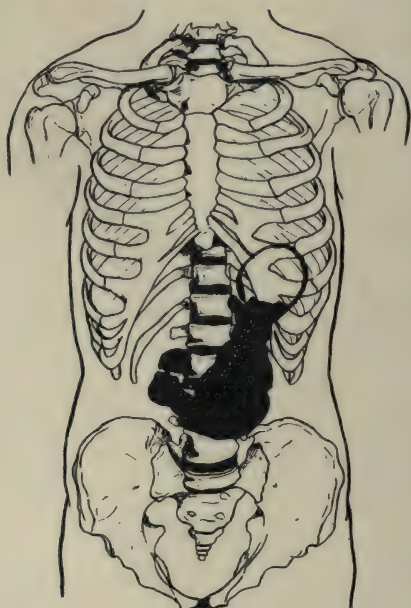


Fig. 18. Tracing from radiogram taken of patient suffering from duodenal irritation. The duodenal cap is well shown, but this is apparent also in normal individuals. The open pylorus allowing continuity between the shadows of the pyloric canal and duodenal vestibule is characteristic of the lesion.

ing portion of the small intestine. In cases of congenital hypertrophic stenosis of the pylorus, the diameter of the lumen shortly after birth is only about five mm. (half the normal). This must be borne in mind in contemplating operations for the relief of the condition (70). The first portion of the duodenum is generally considered to be the most capacious. Its lumen is egg-shaped (85), and when filled with bismuth, its radiographic shadow has been termed the "bulbus duodeni" by Holzknecht. It is also known as the vestibule or antrum. In congenital stenosis of the duodenum this portion may become so distended that it resembles the second pouch of a bilocular stomach. The dilatation of the stomach and duodenal vestibule which occur in such instances, together with the relative constriction at the pylorus, have given rise in some cases to the mistaken diagnosis of hour-glass stomach (74). On the other hand, Dwight, by taking casts of the lumen of the duodenum found the greatest circumference to occur in the second and third portions. He stated that the second part may be very large and yet not over-distended (85).

Congenital duodenal occlusion is a very rare condition. According to Tandler it occurred nine times in 150,000 children in Petrograd. It is probably due to the discrepancy in time between the period of epithelial increase and that of growth in size of the lumen of the gut, rather than to the persistence of the omphalomesenteric duct or artery, or to the presence of amniotic bands (Tandler). Between the thirtieth and the sixtieth day of fœtal life there is an increase in the epithelium of the mucosa of the duodenum, which, occurring in advance of a corresponding increase in the calibre, occasions a blocking of the lumen of the gut. There is most perfect

occlusion halfway during this period, after which the lumen is reformed, and at the end of this period the process terminates (322). With greater exactitude F. P. Johnson describes this process as the temporary obliteration of the lumen owing to vacuolation in the mucosa of the gut. The vacuoles extend throughout the entire length of the duodenum in the embryo of 16 mm., but are most numerous just below the opening of the bile and pancreatic ducts, at which site the lumen is completely occluded. While the lumen again became pervious in Johnson's embryo of 19 mm., it was once more blocked at 22·8 mm. But at the 30 mm. stage the vacuoles have completely disappeared from the duodenum (162).

Hence temporary occlusion of the duodenal lumen is a normal physiological process in early fœtal life. We now know that this process of partial occlusion of the lumen is not restricted to the duodenum, but occurs throughout the intestinal tract. As a rule occlusion or stenosis of the duodenum occurs in the neighbourhood of the entrance of the common bile duct (179). Sometimes the gut may be actually interrupted at this site, in which case it looks as if there might have been some cause at work external to the gut itself (112).

Besides congenital defect of the gut, other causes cited as producing duodenal occlusion are a general inversion of the abdominal viscera and a ring-shaped pancreas, which encircles and is supposed to constrict the duodenum (233).

The mucosa of the first part of the duodenum is smooth and presents neither the plicæ circulares (valvuli conniventes), which commence in the second part opposite to the entrance of the common bile duct, nor the irregular

folds found in the cadaver, especially on the dorsal wall of the second or third part (85).

As in the rest of the small intestine, villi are present throughout, but in addition there are certain glands peculiar to the duodenum known as Brunner's glands. The precise function of their secretion is not understood. They are most numerous in the first part of the organ and in the second part as far as the entrance of the common bile duct. Beyond this point they decrease in number and finally cease at or about the duodeno-jejunal junction (273). Their final distal limit forms, therefore, a very useful indication of the termination of the duodenum. But Villemin does not admit their presence even so far as the duodeno-jejunal flexure (see p. 113).

So-called pressure diverticula of the mucous membrane occur at what are termed weak points. As a rule these are found at or near the entrance of the common bile duct and the pancreatic ducts (180). They may occur either just distal to the common bile duct or immediately proximal to it (293) (276). Sometimes they consist of mucous membrane only; sometimes they also present muscular tissue in their wall. They may occur in the third part and present no relation to bile or pancreatic ducts (157). The various cases in the literature and the suggested etiology have been collected and summarised recently by Baldwin (7). In many cases, if not all, the diverticula are congenital in origin, and have been shown by Lewis and Thyng to be the final result of knob-like extensions from the mucosa (204).

Duodenal ulcer of the peptic variety occurs as a rule on the ventral wall within two or three cm. of the pylorus. Certain cases are recorded in which the ulcer is stated to have occurred in the wall of the second part, but in all

probability the misleading appearance in such instances has been due to the adhesion of the ulcerated bowel to surrounding structures with the result that the affected portion has been brought into close apposition with the right kidney (252). Sometimes the duodenum at the site of ulceration becomes adherent to the liver or gall bladder. This may cause referred pain in the hepatic area, *i.e.*, the right infrascapular region. If the ulcer occur on the dorsal wall, adhesions to the pancreas may develop. In all cases of ulcer with adhesions, it is said that the pain occurs much later after a meal than if no adhesions are present (252), and that the pain also occurs later if the ulcer be on the dorsal wall (252).

Primary carcinoma of the duodenal mucosa is as rare as it is elsewhere in the small intestine. The cases of so-called duodenal carcinoma start in the termination of the common bile duct or in the pancreatic duct or tissue.

The muscular coat of the duodenum was recently studied by Ochsner, who described special sphincteric bands of circular muscle of varying widths and at varying sites in the organ. One of the most common positions was from three to ten cm. distal to the entry of the common bile duct (261). Very quickly, however, the presence of these special sphincters was denied by Boothby (38), and it is now recognised that they represent mere irregularities in the thickness of the circular muscular coat induced by varying irritability and contraction of the muscle after death. These irregularities are numerous throughout the intestine, and are specially obvious in formalin hardened cadavera (339).

Although Ochsner's findings are not substantiated as actual morphological sphincters, it must be understood that the contraction forms represent the living condition

of the duodenum in caricature, just as contraction forms found post-mortem in the stomach present a caricature of the living condition of that organ. Cannon and Blake have shown that after the pyloric sphincter has been cut, rhythmic contractions of the circular musculature of the duodenum prevent too rapid exit of food from the stomach (51). This function of the duodenal musculature replaces that of the pylorus and ensures mixing of the food with the bile and pancreatic juice. Its importance after pyloroplasty is obvious.

Radiographic examination with the fluoroscope, as already stated (p. 80), shows the pylorus to lie at a lower level than in the cadaver. Whereas in the latter it is at the level of the disc between the first and second lumbar vertebræ (transpyloric plane), in the living it lies normally one vertebra lower (on the infracostal plane). In life the first part of the duodenum is often directed almost vertically upwards from the pylorus to the commencement of the second part. Hence the first part lies even ventral to the second. In normal individuals actual examination of the bismuth shadow in the duodenum is difficult because of the rapidity with which the food passes through this part of the bowel. The entire length of the duodenum is traversed in from twenty-five to sixty seconds (201). In addition, the large quantity of digestive secretions which is mixed with the bismuth and its vehicle so reduces the density of the shadow as to make it almost invisible (141). It has, however, been found possible by the use of a watery suspension of bismuth given on an empty stomach, to fill the duodenum and thus more readily to observe its condition (201). Müller claims to have observed contractions in the first part of the duodenum, and states

that he has seen antiperistalsis in the descending part in the absence of organic obstruction (254). Cannon and Blake state that food accumulates in the duodenum and there undergoes the process of rhythmic segmentation to mix with the bile and pancreatic juice (51). Joseph

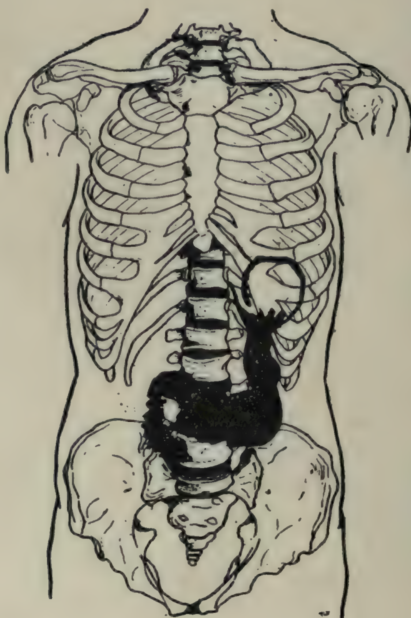


Fig. 19. Tracing of radiogram showing bismuth food in the duodenum as far as the site of crossing of the transverse colon. The position at which the bismuth terminates is near the site of Lane's second kink.

and Meltzer (169) have noticed in the rabbit that there is a kind of receptive relaxation of the duodenum when the pyloric portion of the stomach contracts. A similar

relaxation of the duodenum, in association with a hypertonic stomach, is present in cases of duodenal ulcer.

In normal individuals examined by the ordinary methods, a shadow is seen only in the first part of the duodenum. This is the "duodenal cap" or "bulbus duodeni." No shadow is perceptible in the rest of the organ. If the rapid radiogram is used, small flecks of bismuth are seen scattered throughout the duodenum (201). In the condition known as gastroptosis, and in organic obstruction of the bowel, true duodenal stasis may occur with consequent appearance of the bismuth shadow over more than the first part of the duodenum (140).

The shadow is recognised as being in the duodenal vestibule by the fact that it is unaffected by the peristalsis of the stomach. Such a shadow, which is more persistent than usual, is seen in cases of duodenal ulcer (12). It is not, however, diagnostic of this condition, for it is equally met with in puckering of the duodenum from any cause, as for example, in carcinoma and in cholecystitis (14). In every case the patient must be examined in the horizontal as well as in the upright posture, for the passage of food through the duodenum can be seen with greater ease when the patient is lying down than when he is standing up. Apart from the "bulbus duodeni" a persistent separate shadow in the duodenum is very suggestive of the formation of a pocket produced by spasm, cicatrisation, adhesions, growth or diverticulum (14). Duodenal stasis can be induced even in a healthy patient by giving rapidly a large amount of bismuth food. The stomach is thus weighed down, and apparently constricts the duodenum at the crossing of the superior mesenteric vessels. Such a view is in

accordance with that put forward by Mathieu in acute post-operative distension (227), and will explain the appearance found in Jordan's cases (167), and that mentioned on p. 57 of Barclay's book (14). Cole holds that bismuth does not adhere to the crater itself of an ulcer, but that by the use of serial radiography he can diagnose duodenal ulcer from indentations on the contour of the bulbus produced by cicatricial contraction around the crater. He admits, however, that one cannot always eliminate the puckering due to adhesions caused by gall bladder infections (67). Very frequently in cases of duodenal ulcer the bismuth shadow is not interrupted at the pylorus as it is in normal individuals, but is continuous as a thin streak from stomach to duodenum owing to inefficient contraction of the pyloric sphincter (254). Cole states that by the use of serial radiography if one radiogram out of fifty shows a perfectly symmetrical cap or "bulbus" and a normal pyloric sphincter, a negative diagnosis of duodenal ulcer is justified (68).

The arterial supply of the duodenum comes partly from the cœliac axis vessel via the superior pancreatico-duodenal branch of the gastro-duodenal artery, which itself arises from the hepatic trunk, and partly from the superior mesenteric artery through the inferior pancreatico-duodenal branch. These two vessels form a loop around the head of the pancreas. According to Wilkie, the first part of the duodenum does not get its blood supply direct from the main trunk of the superior pancreatico-duodenal vessel, but through a branch which arises from the proximal part of the gastro-duodenal artery or more rarely from the hepatic vessel or from one of its branches, the right terminal, left terminal or cystic artery. The special artery for the first portion of the

duodenum was called by Wilkie the supra-duodenal vessel, and as usual with the arteries on the intestinal wall, in the majority of cases it presents no anastomosis with neighbouring arterial channels. Even when communication with the right gastric (pyloric) or with the duodenal branch of the right gastro-epiploic artery does take place, it is never very free (345). Hence, as in the appendix, Wilkie believes that interference occurs easily in the blood supply to the first part of the duodenum. In duodenal ulcer, hæmorrhage frequently comes from the gastric mucosa (269). But if one of the pancreatico-duodenal arteries be involved, the superior vessel is always the one affected. It is ulcerated in its course along the first part of the duodenum on its way to the adjacent parts of that organ and of the pancreas. Mayo has drawn attention to the anæmic spot which often appears on the ventral wall of the first part of the duodenum if the gut be stretched by traction on the pylorus. Wilkie considers that in such cases the supra-duodenal artery arises at a high level, and running down to the duodenum, has its lumen narrowed when the artery is stretched by the traction. A similar appearance in the peritoneal coat frequently accompanies duodenal ulcer (229).

The veins of the duodenum call for no special comment.

The lymphatics drain into the nodes immediately around the head of the pancreas. The so-called "duodenal gland," which lies behind the third portion in the root of the mesentery close to the commencement of the superior mesenteric artery, does not drain the duodenum, but is one of the *main* nodes as defined by Jamieson and Dobson (161), and derives its vessels ultimately from the ileo-cæcal region.

The nerve-supply to the duodenum originates in the vagus and splanchnic trunks, the splanchnics ultimately coming from the ninth dorsal segment (133). Hence pain referred from the duodenum is localised in the median line in the umbilical region as in pyloric disease, or may be present to the right of the middle line at the same level (252), especially if adhesions to the gall bladder be present.

CHAPTER VIII.

THE JEJUNO-ILEUM.

THE major portion of the small intestine, constituted by the jejunum and ileum, remains to be considered. As already mentioned, the jejunum commences at a site marked by the beginning of the mesentery, although in certain cases the first inch or so of the jejunum, like the duodenum, may be bound down by peritoneum to the dorsal abdominal wall. In the majority of cases the commencement of the jejunum lies to the left of the median plane.

The jejuno-ileum terminates at the ileo-cæcal or ileo-colic junction, which normally lies in the right iliac fossa. Following on variations in the site of the cæcum, however, the distal end of the ileum may be found elsewhere in the abdomen. As a rule the ileum ascends, but sometimes it descends to its termination, especially if the coils of intestine are arranged in other than the usual manner. Sometimes the terminal part of the ileum is attached to the right psoas sheath by a non-inflammatory fold of peritoneum continuous with the under or left layer of the mesentery. Occasionally the last few inches of ileum are adherent to the cæcum, though again this is not an inflammatory adhesion (329).

The subdivision of the jejuno-ileum into its constituent parts, jejunum and ileum, is ill-defined and of no particular significance. As a rule it is stated that the proximal two-fifths of the small bowel (excepting the duodenum) constitute the jejunum, while the distal three-fifths form the ileum.

Bardeen has stated that there arises from the superior mesenteric artery, opposite its ileo-cæcal branch, a vessel which passes to the small bowel near the junction of its upper and middle thirds. This Bardeen calls the jejuno-ileal artery, and he suggests that the region supplied by this vessel represents the junction between that portion of the small intestine, the primitive coils of which develop within the umbilical cord, the ileum, and that whose primitive coils develop within the abdominal cavity, the jejunum (C. R. Bardeen, *Am. Journ. Anat.*, 1914, vol. 16, p. 427, and *Anat. Rec.*, 1915, vol. 9, p. 137).

The position in the abdomen of the several parts of the jejuno-ileum has been the subject of several investigations. Of late Monk has stated that usually the upper part of the jejunum lies in the left hypochondrium, the lower jejunum and upper ileum to the right of the median line under the liver, the succeeding portion of ileum to the left of the median line in the lumbar and iliac regions and the terminal portion in the pelvis and right iliac fossa (242). This is marked out in surface topography in a very simple manner (see p. 141). Unfortunately this disposition of the bowel is not invariable. Even in the adult, the gut is in many instances otherwise disposed. The amount of bowel in the pelvis naturally varies with the distension of the bladder and rectum, and in pregnancy with the size of the uterus. But the pelvis may contain even loops of jejunum in addition to the lower ileum (329). In the fœtus in many cases the coils, while starting in the left hypochondrium, as in the adult, pass first downward and then upward on the right side of the abdomen to the cæcum, which lies just beneath the liver. In the young child the arrangement is rather that of the older fœtus than of the adult (329). In

embryos of from 7 mm. to 40 mm. in length a part of the intestine is found within the cœlom of the umbilical cord. At the 40 mm. stage it suddenly returns to the peritoneal cavity. The upper part of the portion extruded is the first to return, and the cæcum is the last. As the upper part of the small bowel returns, it assumes its position in the left side of the abdomen (226). The existence in certain children of a loop of jejuno-ileum in the cœlom of the umbilical cord at birth, thus forming a congenital umbilical hernia, may be a persistence of or a return to the condition found in early fœtal life.

As regards the distance from the mouth to the jejunum, it need only be said that Gross has succeeded in passing a tube 150—200 cm. along the alimentary canal, thereby withdrawing a light yellow, cloudy, thick, neutral or weakly acid fluid, which he claims to be typical jejunal juice (119).

The length of the intestine in the cadaver is about 7 to 8 metres. During life its elasticity enables it to lengthen somewhat more. After the intravascular injection of formalin, the length of bowel decreases to 4 or 5 metres. In the infant the gut is relatively longer than in the adult.

The jejuno-ileum is provided with a mesentery throughout its whole length save in those instances in which either the commencement or termination is bound down to other structures by peritoneum.

The successive portions of the jejuno-ileum have certain distinguishing features, some of which are in the gut itself and some in the mesentery, and by these a rough idea may be obtained of the relative distance from the duodenum or cæcum, of any given loop of intestine. These have been described by Monk (242), and more

recently investigated by Latarjet and Forgeot (199), who, however, did not describe any material characters beyond those already stated by the former author. On palpation the upper part of the jejuno-ileum seems thick because of the plicæ circulares (valvuli conniventes) in its walls. As these become fewer, the wall of the gut feels thinner on palpation until in the lower ileum, which is practically devoid of plicæ, the wall feels much thinner than near the duodenum.

The fat in the mesentery increases progressively in amount in the distal direction. But observing this fact one must remember that there is as a rule a much greater proportion of fat throughout the mesentery of the male adult than in that of the female. Latarjet and Forgeot point out that these fatty tufts do not occur in the mesentery of the upper half of the jejuno-ileum of the adult nor anywhere throughout the mesentery of the fœtus or infant. Consequent on the comparative lack of fat in the mesentery of both sexes in the upper jejunum, this portion of gut exhibits in its mesentery close to the bowel wall semilunar areas known as lunules, which are entirely devoid of fat. Lastly the number of arterial arches in the mesentery progressively increases from one to three or four in the downward direction. This increase in the number of arches also occurs, though in less obvious manner, in the case of veins (81), which are more obvious on the right face of the mesentery, while the arteries attain greater prominence on the left face (199).

The mesentery may be the site of development of cysts, frequently of Wolffian origin (259). They are mobile and form tumours palpable through the abdominal wall, though not usually diagnosed as such before operation.

Scattered throughout the mesentery are smooth muscle fibres, homologous with the suspensory muscle of Treitz. Reference has already been made to the thickened portion of this muscle which indicates the duodeno-jejunal junction (see p. 112). It is a muscle bilateral in character, suspending the coils of intestine to the dorsal abdominal wall. In man it is especially thickened where it arises from the two crura of the diaphragm (217). Smooth muscle fibres have also been observed by Rost in the transverse mesocolon near the hepatic flexure (296). Possibly the œsophageal muscular tendrils which connect that organ to surrounding structures belong to this same muscular sheet, which has thickened bands in other situations in lower animals (26). The muscle tends to become changed into fibrous tissue as age advances and in visceroptosis. In the fœtus much more involuntary muscular tissue is found in the muscle of Treitz, in the adult more elastic tissue (76). The muscle was regarded by Keith as being composed of two parts, the upper derived from the diaphragmatic crura and like them composed of striated muscle, the lower from the subperitoneal layer of muscle which also gives rise to the gubernaculum (181).

The action of the mesentery in entero-colic intussusception is worthy of note. Barnard described it thus (20): "It is difficult to understand how the short piece of mesentery to the last three or four inches of the ileum can permit the ileo-cæcal valve to traverse the colon from end to end, and even project from the anus. It must, however, be remembered that this portion of the mesentery is attached about the promontory at the centre of the abdomen. From this centre the mesentery swings round like the hand of a clock, and since the length of

the entering layer is not increased, no extra length of mesentery is required to reach the intussusception as it passes along the colon around this centre. The meso-

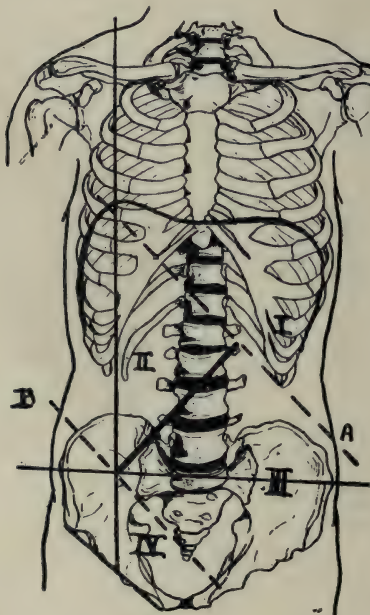


Fig. 20. Chart to illustrate Monk's statements on the localisation of the intestine in the cadaver.

The solid black line represents the rough delineation of the attachment of the mesentery to the dorsal abdominal wall. The broken lines A and B are drawn at right angles to the line of mesenteric attachment. Successive portions of jejuno-ileum are lodged in the areas I, II, III and IV. Compare with figs. 19, 21, and 22.

colon in infants is extraordinarily loose and long. This permits each part of the colon in turn to be drawn towards the promontory around which the intussuscep-

tion travels in quite a small circle until it passes vertically down the rectum and out of the anus."

Occasionally holes are found in the mesentery and may be the cause of internal hernia, which sometimes becomes strangulated. Doubtless some of these holes are of traumatic origin, but the majority are not. Treves states that most are found in the mesentery of the terminal part of the ileum between the ileo-colic branch of the superior mesenteric artery and the last of the vasa brevia to the small intestine. Though not constant, this area, which is conspicuous by its thinness and bloodlessness, is found also in the fœtus and in children under puberty, in whom its diameter measures about 3 cm (329).

The surface topography of the mesentery and small bowel is comparatively simple. In the cadaver the upper limit of the mesentery lies at the level of the transpyloric plane, 3 cm. to the left of the median line. The termination lies at the intersection of the intertubercular and the right lateral inguinal lines. A straight line drawn from the first to the second of these points indicates roughly the attachment of the mesentery to the dorsal wall of the abdomen. As a rule, however, the terminal inch or so of the mesentery is attached obliquely to the dorsal wall in an upward and outward direction. Hence it is a little more exact to indicate the attachment of the mesentery by a line starting at the same point as before, but terminating midway between the right anterior superior iliac spine and the median plane (317). From this a short line drawn obliquely upward and outward to the intersection of the intertubercular and right lateral inguinal lines indicates the terminal upward curve of the mesenteric attachment. The commencement of the

jejunum and therefore of the mesentery is often lower by the breadth of a vertebra in the living than it is in the cadaver. Hence the mesentery in the living may be said to commence on the infracostal plane or just above it. In mapping out, on the surface the position of the small intestine, Monk recommends first that the line of the mesentery be drawn in and then at each end of this a line at right angles to it. Thus the abdomen is subdivided into four areas, one above the mesentery and to the left, one on each side of the mesentery, of which the right lies obliquely above the left, and one below the mesentery comprising the pelvic cavity and right iliac fossa. The first portion of jejuno-ileum lies in the uppermost of these areas, the next in the one to the right of the mesentery, succeeding coils in the area to the left of the mesentery, and the terminal portion in the lowest area including pelvis and right iliac fossa (242).

The mucosa of the jejuno-ileum is about 0·5 mm. in thickness, and very loosely attached to the submucosa. It exhibits plicæ circulares and villi, the latter throughout its extent, the former most abundantly in the upper jejunum, but fewer in a downward direction until in the terminal part of the ileum none are found. They consist of a fold of mucosa with some submucous tissue, and extend for a variable distance round the wall of the gut. The greater number only pass round one-third of the wall. Some, however, pass round two-thirds, and some form complete rings or may even subdivide. As is to be expected, the contraction in length of the bowel after formalin embalming results in the appearance of more plicæ than normally exist in the intestine of the living.

F. P. Johnson noticed in his work on the bowel that when the intestine is distended the villi and glands

become shorter and broader, and that they may even disappear on great distension. From this he argues that, with each dilatation and contraction in normal diastalsis and segmentation movements, the villi change their shape and bring about a more thorough mixing of the contents. He also suggests that by the unfolding of the glands, a greater amount of epithelium is exposed to the intestinal contents (163). While not denying that these phenomena may occur experimentally, one would doubt whether they really are of much effect in distension and contraction under normal conditions in the body.

The lumen of the jejuno-ileum progressively diminishes towards its termination. While it is 37 mm. in diameter near the duodeno-jejunal flexure, it is only 27 mm. in diameter near the ileo-cæcal junction (166). In the jejuno-ileum the same vacuolation of the mucosa which is found in the duodenum occurs during early fœtal life (see p. 125), but the lumen of this part of the gut is never completely occluded. Associated with these vacuolations are diverticula or pockets which occur throughout the length of the small intestine (204). They are much rarer in the upper jejunum than elsewhere and are most common in the ileum (162). The difference between these pockets and those of the duodenum is that whereas in the latter portion of the gut they are often on the side of the bowel adjacent to the pancreas, in the former they are always on the wall of the intestine furthest from the mesentery and invariably point distally (Elze, see 162). It is suggested by Lewis and Thyng that these diverticula may be one cause of para-intestinal cysts (204). Associated with pockets in the duodenum may be accessory pancreatic tissue, and a small pancreas has been known to develop even at the umbilicus in

connection probably with a diverticulum of the embryonic jejunum (352).

The best-known pocket in the jejuno-ileum is Meckel's diverticulum, which is of varying size and situation and which represents the embryonic connection between the mid-gut and the yolk-sac. It is found in 2 per cent. of autopsies and it opens into the ileum usually between two and three feet from the ileo-cæcal junction (34). When the mid-gut is withdrawn into the abdomen from the cœlom of the cord, a portion of the intestine may be left to form a congenital umbilical hernia. Or the entire mid-gut may return to the abdomen but leave a patent diverticulum still connecting the bowel to the umbilicus, and thus give rise to one form of umbilical fistula. The obliterated duct may remain to form a band whose free extremity is attached to another coil of gut, and thus predispose the individual to internal strangulation of a loop of bowel. Lastly, a small diverticulum alone may be present. Barnard (22) noted that in connection with Meckel's diverticulum there may be four varieties of cords which cause obstruction to the bowel :—

1. Cords from the apex of the diverticulum to the umbilicus (atrophy of the duct).
2. Cords from the apex of the diverticulum to an adjacent part of the mesentery.
3. Cords from the mesentery to the umbilicus.
4. Bands from inflammatory adhesions of the diverticulum.

Among mammals Chalmers Mitchell found no trace of Meckel's diverticulum, but it occurs constantly in certain groups of birds, in which it is provided with a mesentery which is an extension from that of the ileum (182). A similar condition is occasionally found in man.

Sometimes the diverticulum is hammer-shaped (113). In certain cases it is difficult to be sure whether the fibrous band present is inflammatory or embryonic in origin (265).

The lumen of the jejuno-ileum may be narrowed or obliterated at any situation. Often, as in Clogg's second case, the occluded portion is near the distal extremity (61). Sometimes a portion both of the gut and of the corresponding mesentery is absent (341), and the condition may or may not be coexistent with a Meckel's diverticulum.

The submucosa of the intestine is dealt with elsewhere (p. 34).

The muscular coat of the jejuno-ileum consists of a superficial longitudinal layer and of an inner circular layer with coarse elastic fibres between. The muscular coat gradually becomes thinner toward the ileo-cæcal junction. Its average thickness is about 0·4 mm. of which the circular layer forms about two-thirds. The longitudinal layer is fairly firmly attached to the overlying peritoneal layer, and is thin at the mesenteric aspect of the gut, where it may even be wanting in places, and thickest in the wall opposite to the attachment of the mesentery. The circular layer shows here and there a hiatus for the passage of vessels and nerves to the mucosa and submucosa (166). In the dissecting-room the jejuno-ileum is frequently found irregularly contracted. This has been shown by Waterston to be occasioned by the formalin of the embalming fluid, acting on areas of varying irritability. In cases in which the irritability of the intestine had been diminished, for example, in septic peritonitis, this irregular contraction does not occur to such an extent.

The normal movements of the bowel are of the segmentation and diastaltic varieties, with perhaps "pendulum" movements. At times the so-called peristaltic rush and possibly antiperistalsis occur. For a full discussion of these the reader is referred to Cannon's monograph (48).

Segmentation movements intimately mix the food with the digestive juices, and expose it to the organs of absorption. They also assist the blood flow from the submucous plexus into the radicles of the superior mesenteric vein and propel the lymph along the lacteals. They only involve about a one centimetre of the gut at one time, and consist of a wave of contraction alone without a preceding wave of inhibition such as occurs in diastalsis. They are stimulated by distension of the gut. When the contraction begins, the ring of muscle becomes refractory and will not respond again to the stimulus of stretching until it is relaxing. Hence a continuous stimulus results in a rhythmic response, and the contraction always occurs in the bulging part midway between the sites of two previous contractions. In man about seven divisions occur in one minute (142), and give rise to characteristic sounds (49).

Another form of slow peristalsis which appears to be allied to the katastaltic movement consists in the onward progression of food in large masses rather than in small divisions. Movements somewhat similar to those of segmentation occur, but instead of merely subdividing the food mass, they reunite it in addition and gradually pass it onward toward the colon (48).

In diastalsis the wave of contraction is preceded by a wave of inhibition, and it extends for four to eight centimetres along the intestine in an ab-oral direction at the

rate of one or two centimetres a minute. Mere mechanical stimulus by distension is probably not responsible for the normal starting of diastaltic waves. The exciting cause is more probably a chemical one, the degree of digestion, the status of the mucosa or some relation between these two factors, because different foods do not pass along the intestine at the same rate. A like chemical cause also is probably the main factor in bringing a diastaltic wave to a finish.

The so-called "peristaltic rush" is essentially of the same character, as other forms of diastalsis, and is probably a response to chemical rather than to mechanical stimulation. It probably occurs in abnormal conditions of the intestine and may be the characteristic movement when purgatives are given. Cannon has noted its occurrence in the human after the giving of a soapsud enema. It may sweep over the entire length of the small intestine, taking but a minute or so to pass the whole distance, or it may affect a large portion only of the canal.

There are conflicting opinions regarding the occurrence of antiperistalsis in the small intestine. Cannon, Kelling and others indicate that such a movement may occur in abnormal conditions (48). The clinical evidence that such a movement may occur is quite equivocal, for as pointed out by Barnard, there is no *need* to postulate this phenomenon in order to account for "fæcal" vomiting (20).

The relation of normal movements of the intestine to the two varieties of intestinal anastomosis is worth consideration. In favour of lateral anastomosis and against end-to-end union, it has been urged that in the former a large contact of serous surfaces can be produced

and that not only may the opening be made as large as is desired, but also that this operation can be performed without regard to the relative size of the intestinal parts to be united. But intestinal openings tend to become smaller with the course of time. In end-to-end suture the transverse cutting of the gut destroys the local mechanism which governs diastalsis. In lateral anastomosis the circular muscular fibres which force the food onward are cut. Contraction of the circular fibres in either one or other of the overlapping intestinal ends cannot force the food onward but only move it over into the inactive part. Unless a co-ordinated advancing contraction of the circular muscular fibres of the two opposed loops should develop, no forward propulsion of the food can occur.

Experimental investigation shows that this condition does not develop, and therefore in lateral anastomosis there is stasis of normal food material at the site of the junction. This is not present in end-to-end suture, which must, therefore, in spite of its greater difficulty and other disadvantages, be held to be the more satisfactory operation of the two (48). Should lateral anastomosis be performed, care must be taken to leave no superfluous intestine beyond the union, lest food stagnate in and distend the proximal loop or invagination occur in the distal loop, with consequent blocking of the opening.

The peritoneal or serous coat of the intestine is adherent to the outer or longitudinal layer of the muscular coat.

It has been pointed out by Latarjet and Forgeot (199) that when the intestine distends, the mesentery does not abut on the intestinal circumference as a radial to the centre of the intestinal circle. The gut curves round to

ie to a certain extent dorsal to the mesentery, so that he latter meets the intestinal circumference at a tangent, he segment of intestinal lumen lying in front and to he right of the mesentery, being much less when the

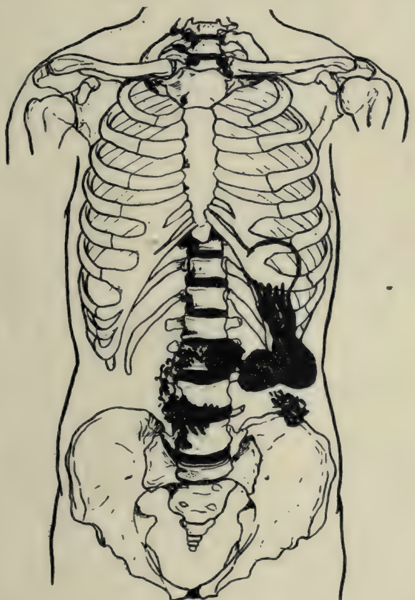


Fig. 21. Tracing of radiogram which shows a bismuth shadow in the upper jejunum. The site was identified at operation as adjacent to the obstruction. The jejunal shadow appears above the left iliac crest. The duodenal bulb is shown together with shadows in the succeeding portion of the duodenum as far as the crossing of the superior mesenteric vessels (the region of Lane's second kink). Compare with fig. 20.

gut is distended than the segment dorsal and to the left.

Radiographic examination shows that food passes along the intestines very rapidly, the average rate for a mixed meal being about one inch a minute, that is, it

reaches the cæcum from three and a half to five hours after the meal (143). If a bolus can be observed in the jejunum, it is seen to be broken up by the segmentation movements and tossed back and forth, but on the whole

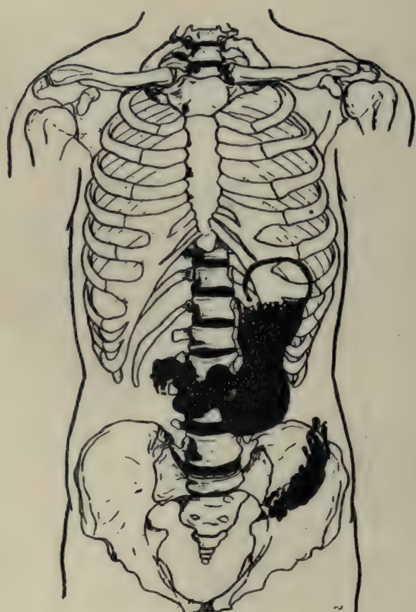


Fig. 22. Tracing from radiogram showing bismuth shadow in the lower part of the small intestine.

The site of obstruction was identified at operation. Compare with fig. 20.

passed onward (14). The segmentation movements occur at the rate of about ten in a minute and a half (142). This rate varies in different animals (48). As a rule the movement is too rapid for observation, and nothing but

a general abdominal opacity is apparent to the eye. If, however, the bismuth contents can be observed, in the upper part of the small intestine they are flocculent in appearance, while in the lower part they present a coagulated character (66). As a rule, the average time before a meal reaches the cæcum is four hours for carbohydrates, five for fat and six for pure protein diet (48).

In tubercular or other forms of adhesive peritonitis, the segmentation contractions are defective, so that shadows may be observed readily in the course of the small intestine. In lesions of the jejunum the symptoms are those of duodenal ulcer (14).

Sir W. A. Lane (198) has described a kink in the ileum about two inches from the ileo-cæcal junction. The kink is said to be produced by the contraction of the mesentery at the point, following thickening of its left or under layer, the thickening being an effort on the part of nature to hold up a cæcum which is otherwise slipping downward because of its dilatation caused by the stasis of contents within it. The idea has been greatly elaborated of late years. The thickening is said to be non-inflammatory, and to have no connection, though there may be association, with appendicitis. It has already been mentioned at the beginning of this chapter. The rationale of postulating the dragging power of the cæcum will be discussed later (see p. 160). There are many facts and considerations which are opposed to the interpretation given by Lane.

As regards the supply of the bowel-wall by blood vessels, it is well to bear in mind that the arteries on the wall itself do not anastomose with each other very freely if at all. Hence in resection of bowel one must be

careful to cut away rather less mesentery than gut and to cut the bowel itself obliquely, thus leaving more of the gut at the mesenteric attachment than at the point diametrically opposite to this, in order that there be no danger of gangrene occurring from loss of blood supply.

The arterial arcade systems in the mesentery have already been discussed (p. 138). Corsy and Aubert describe a particular artery from the inferior pancreatic vessel to the duodeno-jejunal angle (72).

In occlusion of the mesenteric arteries, the collateral circulation is rarely established. This is due to the practical absence of anastomosis between the arteries on the wall of the gut. Faber (98) explained that the inferior mesenteric artery does not take up the work of the occluded superior artery because it is smaller than the latter and cannot suddenly assume the function of the larger artery. In addition, when occlusion occurs in the superior mesenteric artery, the pressure in the superior mesenteric vein becomes reduced to nothing. Consequently the pressure in the portal system is lowered. Blood can flow more freely along the inferior mesenteric vein, and thus it is easier for the blood in the inferior mesenteric artery to flow by its natural channel.

The loss of carbon dioxide from the bowel, especially from its blood vessels, which occurs when the intestine is exposed in abdominal operations is stated by Henderson to be the cause of atony of the gut which sometimes occurs as a complication in such cases, and is part of a condition of acapnia, or, as he terms it, carbon dioxide starvation (137).

The collecting lymphatic trunks of the jejuno-ileum are extremely abundant. The lymphatic nodes are

divided into three groups, one close to the intestinal wall, a second on the primary branches of the superior mesenteric artery, and a third around the main trunk of the vessel. The nodes are most numerous in that part of the mesentery corresponding to the jejunum, and again increase in number around the ileo-cæcal artery (272).

The nerve-supply of the small intestine comes from the vagi and the splanchnics, the former containing the tonic and the latter the tonic inhibitory fibres. For after complete severance of the splanchnics the rate of passage of lean meat along the small bowel was found by Cannon to be greatly accelerated, whereas after total section of the vagi the passage was rendered slower than usual (48). Apparently both sets of fibres are in continuous action. A very full account of the innervation of the intestine was recently given by Müller (255).

Gastro-Jejunostomy.

Having now discussed both stomach and intestine, some reference may with advantage be made to the anatomy of gastro-enterostomy. Much information may be obtained from Cannon's monograph, from which the following account is largely extracted (48).

In spite of many clinical assertions to the contrary, experimental evidence indicates that gastro-enterostomy is never a "drainage" operation. If a stomach upon which this operation has been performed be filled with water, the liquid does not flow out through the artificial opening even when the patient is standing erect. Gravity has very little action, and under ordinary circumstances the food is semi-solid and not liquid like water. The stomach is never a passive reservoir, although the

pressure in the pyloric part is greater than that at the cardiac end. Material does not pass along the alimentary canal by gravity or syphon action, but by the muscular action of the wall. As digestion proceeds, the pylorus rather than the greater curvature tends to become the lowest part of the stomach, and therefore it is impossible to perform gastro-enterostomy in the most dependent part of the organ. The operation cannot relieve the pyloric part of the stomach from irritation by food or gastric juice, but as the alkaline juices which enter the organ through the artificial opening neutralise the stomach contents, the pyloric sphincter is relaxed and food passes on more quickly into the duodenum.

In consequence of the greater fluidity and pressure in the pyloric portion of the stomach, food will tend to pass through the pylorus rather than through the artificial opening which must be made some distance to the left of the pylorus.

But if the pylorus be much narrowed, food passes more readily through the gastro-enterostomy opening. Hence Moynihan has insisted that the operation should be performed only in the presence of demonstrable organic disease (253). As secretion is produced in the jejunum as well as in the duodenum, gastro-enterostomy does not interfere seriously with its production. It is said by Flynn that the digestion of milk is interfered with owing to the inhibition of the secretion of rennin consequent on the regurgitation of alkaline bile and pancreatic juice into the stomach (102). But it has already been observed that probably it is normal to have regurgitation of bile at least into the pars pylorica of the stomach. Moreover one does not find clinically that the patient is less able to digest milk after gastro-enterostomy.

All the same the presence of acid chyme in the duodenum is the normal stimulus to the flow of bile and pancreatic juice, and if the food passes directly from stomach to jejunum these functions are seriously interfered with (51).

Jejunal ulcer may develop after the performance of gastro-enterostomy. Diarrhœa also forms one complication of the surgical treatment. It is possible that both these occurrences result from the leakage of free acid directly through the stoma into the intestine. For this reason the operation should be performed as high in the jejunum as possible where the bowel may be relatively immune to acid contents.

The posterior operation is usually carried out. The incision in the stomach should be near the pylorus and as large as possible in order to provide against subsequent contraction of the stoma. It should be parallel to the gastric vessels, that is, at right angles to the greater curvature, and its lower extremity should nearly reach the greater curvature. There is no need to twist the jejunal loop. The incision in the jejunum being longitudinal, the circular muscular fibres are paralysed. If the stomach is distended, the margins of the stoma are kept apart and the intestinal wall practically forms part of the floor of the stomach. For this reason the opening into the intestine becomes a valvular slit, and kinks are liable to form at the proximal and distal margins of the stoma. Therefore it is well to fix the bowel to the stomach for a few centimetres both proximal and distal to the artificial stoma. A kink in the bowel at the edge of a stoma is a very different matter from a kink in an intact portion of the gut. In the latter case, the contraction of the circular fibres proximal to the kink invariably

forces the contents past the mechanical obstruction. In the former case, there being no intact circular fibres immediately proximal to the kink (owing to the presence of the stoma), there is no muscular force to overcome the resistance of the kinked bowel, and the contents will therefore stagnate at the site of the kink. Lest the necessary opening in the transverse mesocolon should contract and assist in the formation of kinks, its margins should be sutured to the stomach wall.

After gastro-enterostomy, the following misdirected currents may occur, any one producing a vicious cycle. They are the cause of the regurgitant vomiting which sometimes occurs as a complication of the operation.

(1) Duodenal contents through the pylorus.
(2) Fluid from the stomach into the afferent loop.
(3) Fluid from the afferent loop into the stomach.
(4) Fluid from the efferent loop into the stomach (248).

CHAPTER IX.

THE CÆCUM, APPENDIX AND PROXIMAL COLON.

THE proximal colon is that part of the large intestine which is developed from the mid-gut. It comprises the bowel from the ileo-cæcal junction to the splenic flexure and is anatomically subdivided into the following parts: the cæcum with the appendix, the cæco-colic sphincteric tract (in some animals), the ascending colon, the hepatic flexure and the transverse colon.

I. THE CÆCUM.

The cæcum is the commencement of the large bowel, and lies proximal to the orifice of the small into the large intestine. In the majority of autopsies it is found entirely within the limits of the right iliac fossa, but its situation may vary not only in different individuals, but in the same person from time to time. As a rule the terminal part of the ileum passes upward and to the right to open into the large bowel, thus forming acute ileo-cæcal and obtuse ileo-colic angles.

The delimitation of the human cæcum from the colon is, in many cases, not well-marked. Struthers defined it as occurring at the site of the anterior and posterior frænal furrows (316). Berry observes that these may not be obvious on the external aspect, but he suggests that in such cases the limit is fairly accurately indicated by the mid-point between the upper and lower borders of the ileum at its junction with the large intestine (30).

Originally the cæcum had a mesentery, but in consequence of the distension of the organ in early life its mesentery is frequently so small as to be negligible. In such cases, however, the cæcum is almost entirely surrounded by a peritoneal coat. Berry states that the viscus is surrounded by peritoneum in 94 per cent. of cases, and he goes so far as to deny the presence of a mesocæcum altogether (30). Around and about the cæcum are certain pockets of the peritoneum These vary greatly from individual to individual in their precise limitations and extent. Many were figured by Lockwood and Rolleston (210), but in general terms most may be gathered into one of three groups, ileo-colic, ileo-cæcal and retro-colic, which are thus named from their positions relative to the gut.

As previously mentioned (p. 135), the termination of the ileum and the cæcum may be closely bound together. This sometimes consists in no more than a peritoneal band uniting the two, such as the one figured by Morley in his recent article on Jackson's pericolic membrane (246). Lockwood has pointed out that in the eighth month of fœtal life there is a peritoneal band connecting the cæcum to the right genital gland in both sexes, and that if descent of the genital gland is imperfect, descent of the cæcum may also be partial (208). It is not here suggested that one of these conditions is the cause of the other, but they may be associated, and in a case in which the symptoms are those of appendicitis, but in which the signs point to an involvement of the right hypochondrium and not the iliac fossa, examination of the scrotum for presence of the right testicle may give some assistance in the differential diagnosis between gall bladder and appendicular disease. Probably this peritoneal fold is

related to the genito-mesenteric fold described by Reid, to which reference will again be made (p. 169).

The cæcum can be distinguished first in embryos of 65 mm. (Tarenetzky, quoted by Lewis (203)), some time after the first appearance of what ultimately becomes the appendix. Originally starting as a backwardly directed diverticulum of the gut in the region of the left hypochondrium, the cæcum reaches the right hypochondrium beneath the liver, and then gradually passes down to attain its adult position in the right iliac fossa, which, according to Keith, it reaches about the time of birth (178). In this course two bends occur, one when the cæcum, under cover of the liver, begins to pass downward toward the iliac fossa, and the other when it is in the fossa itself. Lewis (203) states that in a 95 mm. embryo the appendix is still in contact with the liver, and the first U-shaped bend of the diverticulum occurs, which ultimately forms cæcum and appendix, while the descent of the cæcum to the iliac fossa has already begun. At the 218 mm. stage the appendix has taken up its normal position. The bending of the large bowel on itself is described by Toldt (325) (326), and by Parsons (266). The former of these authors shows that the formation of the ileo-cæcal valve is probably brought about by this bending. Later, toward the end of fœtal life and in infancy, when expansion of the cæcum and colon occurs, they still further bulge over the termination of the ileum, and increase the size and extent of the cusps of the valve.

In certain cases the cæcum may be entirely absent, the colon and ileum being normally constituted and even the appendix represented (93). Again the cæcum may be present, but in consequence of imperfect rotation and

descent, the ileo-cæcal valve may be imperfect (266).

It is obvious that the cæcum may never reach its normal position in the iliac fossa. It may be that the organ itself has not descended or it may be but one of the abdominal organs which are in abnormal positions associated with faulty rotation of the mesentery. Of the latter a marked case was recorded by Riechelmann (283). Not only may the cæcum be found at autopsy short of its usual position, but the organ may overshoot its normal site and lie within the true pelvis. G. M. Smith states that in 1,050 autopsies recently performed, the cæcum was found in the right iliac fossa in 882, between the liver and the iliac fossa in 63, on the left side of the abdomen in 5, and in the pelvis in 100 cases. Of the pelvic cæca, 66 occurred in females and 34 in males (311).

A condition known as cæcum mobile or cesspool cæcum has received considerable attention during the past few years, and a good historical review of the subject has been published by Sailer (299). This "wander" cæcum, which is mobile in view of the possession of a mesentery by it and by the lower part of the ascending colon, is said to cause mechanical obstruction in three ways: the formation of a kink near the hepatic flexure; the doubling of the cæcum on the colon; volvulus of the cæcum. Klose states that the condition is present in 10 per cent. of all persons. On the other hand, Cramer and Bevan have strenuously denied the pathogenicity of cæcum mobile. Of this it is certain that the cæcum varies in its precise site even in the same individual from time to time. A cæcum which is in the pelvis one day may be shown by radiography to lie in its normal iliac position the following day. It is difficult to understand how mere mobility of the cæcum could cause the conditions

attributed to it, or how the "kinks" produced could have much obstructing power. Anatomical variation need not necessarily be pathogenic. In a radiogram the organ sometimes appears subdivided at the brim of the

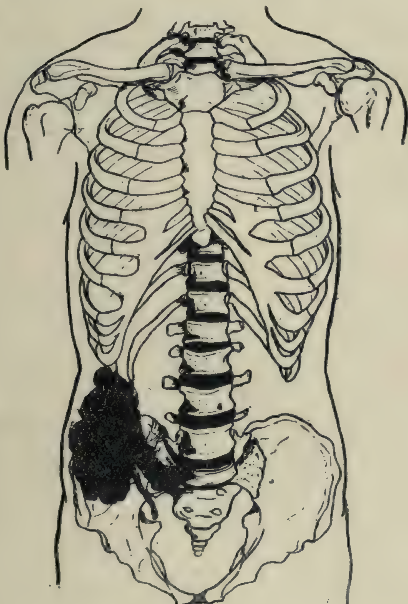


Fig. 23. Tracing from radiogram showing bismuth shadows in the terminal portion of the ileum, the cæcum and the appendix. Compare with fig. 20.

pelvis so that there is an upper iliac part and a lower pelvic portion which may be filled with stagnating food. It may be that there is some, perhaps even a considerable amount of atony in the wall of such a cæcum, but if this be so, the cause of the trouble is too deep-seated for one

reasonably to expect a cure from plication of the wall itself or from the various methods of slinging up the organ.

Sometimes the cæcum is to be found in a right inguinal hernial sac. According to its initial peritoneal

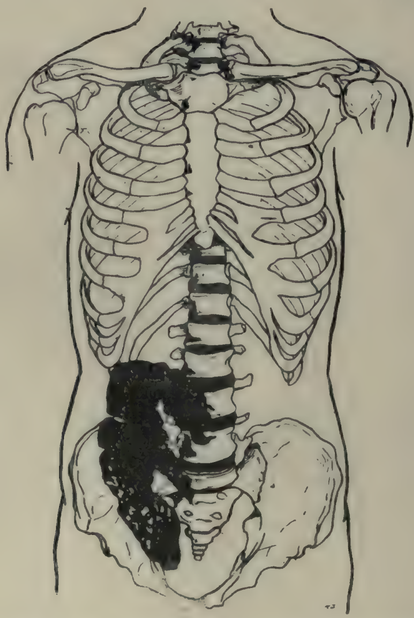


Fig. 24. Tracing from radiogram showing the cæcum dipping over the pelvic brim into the cavity of the true pelvis.

This may be a variation in position from the situation shown in fig. 23. Such a cæcum as is here figured is not necessarily pathological.

relations its relation to the sac will vary. Thus a "wander" or floating cæcum will be found entirely within the sac, or as an adherent organ incompletely surrounded by the sac (see Cavaillon et Leriche (57)).

Although volvulus of the cæcum naturally falls to be discussed at this stage, it will be better to postpone its full consideration until the fixation of the proximal colon has been described.

After a bismuth meal the *x*-ray shadow normally appears in the cæcum in about four and a half hours. The organ should be nearly empty in twelve hours, and at the end of twenty-four hours it should contain only traces of bismuth adhering to its walls (139). In some cases of cæcal atony, among which would be included instances of cæcum mobile, there may be stagnation of food material for two or three days (299) forming the so-called cess-pool cæcum. The elongated and mobile cæcum, becoming twisted on its vertical axis, may give rise to one form of volvulus of the organ (71).

As already mentioned, the cæcum in the majority of instances occupies the right iliac fossa. Its surface topography is simple. The organ extends from the intertubercular line above to the inguinal ligament below, and from the anterior superior spine laterally as far as the intersection of the intertubercular and right lateral inguinal lines in the medial direction. There is said to be some relation between the relative development of the cæcum and the position of the appendix, but this can have no direct clinical importance. When empty the cæcum is separated from the ventral abdominal wall by small intestine and omentum. When partially distended, it comes into contact with the deep surface of the abdominal wall and frequently can be palpated. As regards the percentage of cæca which can be palpated, statements vary. Obrastow (260) could distinguish the organ in 51 per cent. of men and in 58 per cent. of women. Haussman claimed to be able to palpate it in

80 per cent. of cases (130). Sailer, however, could distinctly identify the cæcum by palpation in 20 per cent. only of his patients. On palpation the cæcum varies from a soft indefinite movable mass to a distinctly palpable tympanitic balloon-like body. According to Sailer, palpation reveals it in some cases nearer the anterior superior spine, in others nearer the middle line. Also the lower border varies from two inches below to one inch above the intertubercular plane (299). But of course neither palpation nor percussion can do more than give the barest and frequently the most misleading idea concerning the site and size of the organ. Pressure on the cæcum may elicit gurgling if the organ contain gas. An hour or two after the arrival of food material as shown by the *x*-ray shadow, the resonant note is lost over the cæcum when the patient is examined in the vertical position (139). Sailer observes that in the atonic condition the cæcum is felt as a somewhat indistinct cylindrical or pear-shaped mass which can be passively displaced.

The relation between the position of the cæcum and the abdominal wall makes the formation of a cæcal fistula a simple matter. A large opening can be made which easily closes afterward.

The position of the ileo-cæcal valve is indicated by the intersection of the intertubular and right lateral inguinal lines. Of the two cusps the lower is much the larger. Thompson has shown that in fœtal, infantile and adult cæca alike, the orifice between the cusps, is directed downward and outward. In some cases the opening looks much more downward than outward (324). About the same time at which the resonant note is lost with the accession of chyme into the cæcum, the cæcal sounds

reach their maximum. If there be irritation of the surrounding peritoneum, the ileo-cæcal valve closes and as nothing passes from ileum to cæcum the sounds cease. Hertz on this account suggests the value of cæcal auscultation in appendicitis of doubtful extent. If no sounds are to be heard over the cæcum in a case of appendicitis in which there is absence of vomiting and the patient has not been taking fluid, peritonitis is likely to be present (139). This necessitates the existence of an efficient ileo-cæcal sphincter, which has been shown to be present by Keith (183) and by Elliott (91), there being normally no backflow of food material from colon to ileum. Upon this sphincter neither the vagus nor the sacral nerves exert any influence. Stimulation of the splanchnics, however, causes the sphincter to contract, though at the same time it inhibits the circular muscle in the wall of the ileum and colon adjoining the sphincter (91). The same result may be obtained experimentally by exposure of the peritoneum to cold air. This sphincter is competent to prevent regurgitation of food passing from the stomach onward, but does not exclude from the ileum food travelling from the rectum upward. Thus large nutrient enemata have been shown to pass through the ileo-cæcal orifice into the lower coils of small intestine. These enemata were not, however, given to human patients, but experimentally to various animals, and were of such an amount as to entirely fill the large intestine (48). The function of the sphincter is to prevent regurgitation of chyme into the ileum when the anastalsis in the proximal colon forces the foodstuff back into the cæcum (see note, p. 230).

In certain cases the ileo-cæcal sphincter is inefficient. According to Hertz this results in a tympanitic distension

of the central parts of the abdomen (148). Case observes that instances are frequently described as ileal kinks which are no more than overloading of the distal end of the ileum through incompetency of this valve (56).

The function of the cæcum is not yet by any means understood. As early as 1814 Home performed experiments which suggest that some substances such as rhubarb and fats may be partially absorbed in the organ (153). In 1904 Macewen observed the secretion of a viscid alkaline fluid, the function of which is apparently to neutralise the acid chyme as it passes through the ileocæcal orifice (222). It is owing to the absence of this neutralisation that the skin surrounding a cæcostomy wound may become corroded and inflamed as it does when a fistula is made between the skin surface and the lower ileum. The digestion of surrounding skin does not occur in colostomy wounds even if they are made as high as the transverse colon. Barnard has suggested that certain cases of ulcerative colitis may also be due to the failure of the cæcal glands to neutralise the corrosive acid chyme (20). Macewen states that the cæcum maintains an attenuated culture of bacillus coli to assist in digestion (222).

At birth the calibre of the cæcum is relatively much less than it is a few years later when the organ has become sacculated from the presence within it of chyme and gas. This distension appears about the age of four to five years. As the individual grows to adult age, the cæcum frequently becomes the most capacious portion of the large intestine, and in old age, especially in females, may be very distended (266). Of all the large intestine the cæcum has the thinnest wall. It is only one to one and a half millimetres in thickness. This is

made up of serous, muscular, submucous and mucous coats, which on the whole present very few special characteristics. Unlike that of the colon, the serous coat of the cæcum presents no appendices epiploicæ. The three tæniæ or bands of longitudinal muscular fibres extend from the colon on to the cæcum, and meet at the orifice of the appendix. Parsons observes that possibly the transverse constrictions on cæcum and colon are caused by the passage of blood vessels around the gut (266). Further particulars concerning the cæcum can better be stated with the general description of the proximal colon.

II. The Vermiform Appendix.

The vermiform appendix, which is originally the continuation of the cæcum, has, in view of the eccentric growth of the latter organ, become attached to the dorso-medial aspect of the cæcum. Unless bound down by adhesions its closed end is free and wanders within limits in the peritoneal cavity. It is essential to remember this characteristic and to realise that the appendix varies in position, not only in different individuals, but in the same individual from day to day (2). Hence statements with regard to its exact site must be accepted on the understanding that the position is more or less accidental. This view is confirmed by the radiographic studies of Cohn, who watched the appendix, when filled with bismuth, move of its own accord around the cæcum, and in addition follow the peristaltic movements of the latter organ (63). The position of the appendix also varies with the attitude of the patient.

The appendix is said to be found most frequently

behind the terminal loop of the ileum and the mesentery. This covering of the organ by the mesentery results in restriction of the suppurative process which follows inflammation. If the appendix happen to be lying in front of the mesentery, as it sometimes does, when appendicitis occurs, it is in a very dangerous position, for the abscess from an appendix in this situation cannot easily be shut off from the general peritoneal cavity, and is frequently fulminating in type (23). Other common positions for the appendix are, first, dorsal to the cæcum or even the ascending colon, should that organ possess a mesentery, and, secondly, hanging downward into the pelvis, where its tip may become adherent to any of the internal genitalia in the female (225).

Preileal or precæcal positions for the appendix may be considered exceptional (225). But whatever its site, the appendix is always intraperitoneal. Those cases which are stated to be extraperitoneal are in reality instances of retrocæcal appendix surrounded by adhesions. Such an appendix may originally have lain in a retrocæcal pouch or in the angle between the cæcum and the lateral abdominal wall (24). In either case the occurrence of adhesions would lead to the same final condition. This type of abscess will probably drain into the right kidney pouch. It is therefore essential that the pouch should be investigated, and if need be, drained. The appendix, when dorsally placed, may lie on the psoas sheath, to which adhesions may bind it. Thus, it is stated that some cases of appendicitis of sudden origin may be due to actual rupture of an appendix previously adherent to the psoas sheath, consequent on some exertion involving the violent contraction of this muscle (24). Normally the appendix possesses a mesentery,

which however reaches the tip in 50 per cent. only of cases (243).

Of various relations of the appendix, certain of those to peritoneal folds may be mentioned here in view of the attention recently drawn to them by Macnaughton-Jones (225). Occasionally the appendix may bear some more or less intimate, though adventitious, relation to the plica vascularis, the fold of peritoneum covering the genital vessels and nerves which, on the way to their distribution, pass close to the ileo-cæcal region behind the terminal part of the ileum. Rolleston reported a case in a boy of six in which the plica vascularis had obtained an attachment above to the cæcum and appendix (292). Again Reid has described, as distinct from the plica vascularis, a genito-mesenteric fold in the fœtus on the right side from the mesentery to the genital gland. Later some part of this becomes the duodeno-renal ligament, while the rest disappears. The ileum or appendix may become attached to it secondarily (277). This secondary connection may, as Reid suggests, become a pathway of infection between the appendix and the genital gland (278). The relation of the appendix to radicles of the portal system will be dealt with in the section on veins of the proximal colon. It must not be forgotten, however, that the right common iliac vein and its main tributaries lie close to the appendix, and in certain instances phlebitis has developed in these veins after appendicitis (103). Thrombosis may occur in the femoral veins. The etiology in the last group is obscure and frequently the left vein is involved (236). There is also the possibility of the occurrence of pressure necrosis of the external iliac artery by the rubber tube after drainage of an appendicular abscess (53).

The appendix is not a vestigial but a specialised portion of the alimentary canal (30). Its length averages 9·2 cm., and is not so variable nor so great as is frequently asserted (31). It attains its greatest length and diameter between the ages of twenty and forty years, and there is no relation between its length and the size of the cæcum (31). In children it is proportionately longer than in adults (243). Bryant noted that it is usually about one centimetre longer in the male than in the female (43).

In view of its varying position, only the base of the appendix, where it is fixed to the cæcum, can be used for topographical purposes. Liertz found that the base of the appendix lies as a rule under normal bodily conditions about one to two centimetres lateral to the right trisection of a line joining the two anterior superior iliac spines (205). It is usually identified on the surface by a point on the right lateral inguinal line two to three centimetres vertically below the point of intersection with the intertubercular plane. McBurney's point, midway between the anterior superior iliac spine and the umbilicus, indicates the site of greatest tenderness in the majority of instances, and not the origin of the appendix from the cæcum. Ewart has utilised the dorsal topography of the appendicular region in a new test recently published (97). Over both posterior superior iliac spines and the adjoining region of sacrum and ilium are two areas normally of subresonant dulness. The dulness is largely due to the presence of the common iliac blood vessels. That on the right side is duller than the left patch, presumably because of the presence beneath it of the tissues of the ileo-cæcal junction. The right area, or its immediate environment, becomes quite dull in

certain types of appendicitis, such as retrocæcal abscess, in which the ventral localising signs are ill-marked or absent. Or there may be an area of resonance over the patch, probably due to gas in the abscess, accompanied by dulness in the immediate neighbourhood. After operation the right subresonant patch becomes equally resonant with the neighbouring area or may even be tympanitic.

Two other tests depend on tenderness localised at McBurney's point and perhaps even on pain in the right iliac fossa on distension of the cæcum with gas in patients suffering from appendicitis. The first of these, Rovsing's test, is carried out by pressure over the descending and iliac colons. It is supposed that the forcing of contained gas backward along the large bowel distends the cæcum. But this test is not always positive, perhaps as Hertz suggests (146) because there is not enough gas in the descending colon. The other test is that of Bastedo. This is performed by pumping air through the anus and thus artificially distending the cæcum (25).

The orifice of the appendix into the cæcum is marked by the inconstant valve of Gerlach, of which the function, if any there be, is not known.

The diameter of the appendix according to Bryant (43) and Berry (31) is about six millimetres at the base and five millimetres at the apex in the adult male, slightly less in the female. The lumen of the appendix filled with bismuth can be seen in some radiograms, but in spite of the assertions of Cohn and others it is not yet agreed by all investigators that bismuth can be traced in the lumen of the normal appendix. Occasionally diverticula occur from the lumen of the organ as in any other

part of the large intestine (135). In many cases the lumen of the appendix is obliterated. This was regarded by Zuckerkandl in 1894 as an involution phenomenon in which inflammation plays no part (355), an opinion to which Berry agreed the following year (31). After or about middle age partial obliteration is the rule, and total obliteration occurs at the age of sixty or seventy years (31). Recently, however, Berry and Lack have reversed the opinion of 1895, and have decided that obliteration of the lumen is invariably pathological, being in every case associated with an interstitial fibrosis, the result of vascular obstruction and possibly part of a general arteriosclerotic condition; and furthermore, that obliteration may occur at any period of life (32).

The wall of the appendix averages in the adult about two millimetres in thickness. The mucosa is thicker and better defined in the child than in the adult (166). Like the submucosa it is infiltrated with lymphoid tissue, which is present in all embryos of 170 mm. and upwards. Contrary to the opinion of Berry and Lack (32), both diffuse and nodular forms of lymphoid tissue are present at birth (164). The lymphoid tissue diminishes again after middle life (32). Concerning the relation of the cæcal region to the absorption of fat, Owen Williams made some interesting observations (347). Calcium soaps are formed in the intestinal wall. In excess they form sand, and associated with this are colic and sometimes mucous colitis. The appendix is no exception to this rule, and a ring of calcium soap may be formed in its submucosa, thus cutting off part of the nourishment of the mucous membrane and rendering it more vulnerable to bacterial attack. Probably the causal factors are the stearic and palmitic acids of animal food, for the

soaps of these, unlike that of oleic acid from vegetable food, are saturated and hence are absorbed with greater difficulty. It is noteworthy that regeneration of mucous membrane may occur very rapidly in the appendix (332).

The muscular coat, which is 0·6 to 0·7 mm. thick, consists of outer longitudinal and inner circular fibres, at intervals in which are gaps not less than 1 mm. wide and usually situated at the attachment of the meso-appendix. Through these the blood and lymph vessels pass to the mucosa, and the subserous and submucous tissues come into contact. Lockwood suggested that these gaps may be important pathways by which infection may travel from the mucosa to the peritoneum (209).

Although the arterial supply of the appendix will be described with that of the proximal colon, it is convenient here to refer to the fact that the entire supply arrives by a small vessel, coming in the majority of instances from the posterior cæcal artery. The blood supply of the appendix is therefore easily shut off, and in this the appendix differs markedly from the gall bladder. As Mayo Robson pointed out (287), gangrene depends on three factors, thrombosis of nutrient vessels, bacterial infection, absence of drainage and therefore tension. In consequence of its small opening into the cæcum, the appendix is liable to the third of these; the second is frequently present, and the first readily follows either of the others. Hence the frequency of gangrenous appendicitis. Examination with the *x*-rays of injected specimens reveals a much larger supply of blood vessels than former anatomical studies have led us to believe (104); nevertheless the clinical fact remains.

III. The Cæco-Colic Sphincteric Tract.

Immediately beyond the ileo-cæcal orifice in certain

animals, such as the rat, which possess a well developed cæcum, there is a specialised portion of the colon called by Keith the cæco-colic sphincteric tract. This is seen in its most distinctive form in graminivorous and vegetable feeding birds. Keith also presents some evidence of its functional existence in man (184), although it must be admitted that its importance has not yet been fully substantiated.

IV. The Ascending and Transverse Colons.

The parts of the proximal colon, which still remain to be described, are the ascending and part of the transverse colons together with the hepatic flexure. The separation of the colon into proximal and distal portions is based upon considerations of physiology rather than those of anatomy. It is still uncertain at what point in the transverse colon these two portions meet. Nor is it known as yet whether the site is the same in all individuals. Hence for purposes of anatomical convenience the whole of the transverse colon will be included in the proximal colon, there being always the reservation that the physiological limit may be overstepped by this subdivision. It may be observed that in the human subject the blood and nerve supply to the colon proximal and distal to the splenic flexure are distinct, although the gross features of the two portions of the bowel are not in themselves sufficient to indicate any marked difference in function.

The ascending colon is a short length of bowel extending upward from the right iliac crest to the region of the hilum of the right kidney. At this level it turns to the left under the liver to become the transverse colon, the bend being known as the hepatic flexure. In length

the ascending colon averages 10–12 cm., though it frequently increases to 19 cm., or even more in old people (166). As an anatomical entity it may be wanting, the cæcum apparently being continuous with the transverse colon. In cases of nephroptosis it may be very far from its normal position (3). The surface topography of the ascending colon may be mapped out as extending in a vertical direction lateral to the right lateral inguinal line from the intertubercular plane to the level of intersection of the mid-axillary line and the tenth rib, at which site lies the hepatic flexure (323).

Rost states that he finds constant a thickening of the circular muscular coat in the transverse colon about three fingers' breadth from the hepatic flexure. This he considers to act as a valve, but he examined only five cases (296). Radiographic examination however appears to confirm this (285).

The splenic flexure lies higher and deeper in the abdomen. Its level is that of a plane passing through the intersection of the left mid-axillary line with the upper border of the ninth rib (323). Between the two flexures lies the transverse colon, the disposition of which in the abdomen is very variable. In subjects preserved with formalin it usually presents a downwardly directed hepatic loop at its right extremity. Radiographic examination shows that this loop is transitory in character; it is sometimes present and sometimes absent in the same individual. Beyond the hepatic loop the transverse colon proceeds across the abdominal cavity in intimate relation with the greater curvature of the stomach (2), on the state of distension of which its position largely depends. In the adult the transverse colon is usually about 50 cm. in length (166). The colon

in abnormal cases may have a very different disposition. It may lie entirely to the left of the median line (354), or form merely ascending and descending limbs (349), or part only may be displaced (123).

The method of fixation of the proximal colon to the dorsal abdominal wall is usually the following. The cæcum is provided with a mesentery. The ascending colon and hepatic flexure are bound directly to the parietes without the intervention of a mesocolon. Over the head of the pancreas a mesentery again appears for the attachment of the transverse colon, and is lost only at the splenic flexure. Occasionally there is no attempt at direct fixation of the ascending portion, and the whole of the proximal colon, in such cases, possesses a mesentery. Usually, however, some part of the ascending colon, especially near the hepatic flexure, is bound down, the lower part alone having a mesentery in common with the cæcum. G. M. Smith states that among 982 autopsies, the former condition was found 17 times and the latter 304 times (311). Either arrangement renders possible a twisting of the ileo-colic region of the gut round the superior mesenteric artery as an axis, and thus one variety of volvulus of the cæcum is produced (71). Certain additional peritoneal bands are found in some subjects. Of these the phrenico-colic ligament is described as constant. It connects the splenic flexure with the abdominal wall at the point where the diaphragm arises from the eleventh rib. Another fold binds the hepatic flexure in similar manner to the abdominal wall. A third is present on an average in one subject among four, and connects the transverse colon and duodenum to the gall bladder. The chief interest of all these bands is that they form centres around

which peritoneal adhesions of inflammatory origin may develop. Adhesions of such a nature are especially common around the gall bladder, but are often found in the regions of the hepatic and splenic flexures, which, be it observed, are gentle curves when seen in *x*-ray examinations from the side and not acute flexions (145), rendering these bends in the gut angular and binding the adjacent loops of bowel more closely together. In spite of many assertions to the contrary, there is no conclusive evidence that adhesions in these areas cause any stagnation or obstruction to the passage of contained food material. The two flexures, nevertheless, when surrounded by adhesions have served Lane as sites for two of his so-called kinks.

The nephro-colic ligament, on which emphasis is laid by Longyear, may be mentioned here. This consists of the fibrous tissue between the right kidney and the colon. Longyear has stated that nephroptosis is really secondary to coloptosis, and that the kidney is dragged out of place by its attachment through this ligament to a prolapsed colon (214). The view has not met with general acceptance.

Other adhesions of more obscure origin occur in the region of the proximal colon, but it is well to bear in mind that the large intestine generally, and the proximal colon especially, is the most frequent site for peritoneal adhesions of inflammatory type (240).

Jackson's membrane is found in children and even in infants as well as in adults. It runs from the right lateral abdominal wall to the ascending colon, and sometimes to the cæcum, at or in the neighbourhood of the ventral tænia muscularis. According to Morley it is in some cases the continuation of the great omentum,

although the arrangement of blood vessels in it does not suggest such an origin. The vessels are arranged in parallel from the abdominal wall toward the gut. Flakes of fat are present in its substance. Morley states that his cases showed it to be of congenital origin, although he perhaps underestimates the difficulty of distinguishing congenital from acquired peritoneal membranes. According to Morley, the membrane may co-exist with a complete mesentery to the ascending colon (246). Such cases as that of Bevan (33) would indicate that sometimes, at any rate, the membrane may be acquired as the result of a pathological condition in adult life, and Jackson himself doubts the uniform origin of the membrane in all cases (158). At any rate, Eastman claims to have produced the membrane experimentally in rabbits (86).

Among such bands and membranes should be mentioned the contracted psoas parvus tendon, the result of a chronic inflammation following on appendicitis or typhlitis. Macdonald has recently drawn attention to this as a cause of stagnation of contents in the cæcum, but he produces no radiographic evidence in support of his view (221).

The sacculated condition of the colon itself is said by Parsons to be due possibly to the constricting influence of blood vessels (266), and to the contraction of its longitudinal muscular coat, which is arranged in three bands, one of which lies on the ventral aspect of the gut, one on the side proximal to the small intestine, and one on the side distal to it. As already pointed out, these three tæniæ meet at the orifice of the appendix.

Along the gut are numerous fatty tags known as appendices epiploicæ. They occur especially along the ventral tænia and frequently contain small diverticula

from the mucous lining of the colon. They are not found on the cæcum.

Diverticula of the lumen of the colon are not infrequent about the ileo-cæcal region. In the colon they are present along the mesenteric border and in the appendices epiploicæ, but are much rarer in the proximal than in the distal colon. When present they are frequently found in stout people beyond middle life, and more frequently in males than in females (316). They are subject to the same complications as is the appendix.

In the proximal colon the last of the food disappears, cellulose may be so transformed that it can be utilised in the body, and water is absorbed (50). Great thirst is one of the usual complications of a cæcal or right inguinal colostomy, and in such cases the patient soon suffers from vomiting, which is relieved by the subcutaneous infusion of fluid (256).

The contents of the transverse colon are almost as solid as those of the sigmoid (290). The mere passage of the fæces over the mucosa seems to have some special significance, for in Williams' case, when no fæces were allowed to pass into the colon, purpura hæmorrhagica developed, but disappeared as soon as the fæces pursued their normal course (241).

The mucosa is thicker than that of the small intestine, but paler and less well supplied with blood vessels. It shows temporary longitudinal folds, which disappear on distension of the gut, but on it are neither plicæ circulares (valvulæ conniventes) nor villi. The last-mentioned disappear from the mucosa in early fœtal life (164). There are, however, semilunar folds which run transversely to the long axis of the bowel, and which separate the interior of the bowel, especially when dried, into

haustra or saccules: these are known as plicæ semilunares. Glands are distributed most thickly in the ascending colon. They are less closely packed in the cæcum and still less in the transverse colon (128). Peyer's patches are only exceptionally found in the proximal colon of man (166), though present in many lower animals (83). The intestinal wall is thinnest in the cæcum and gradually increases in the distal direction (128). According to Roith, the cæcum and ascending colon contain on an average about twice the amount of material present in an equal length of transverse colon, and from three to five times as much as an equal length of descending colon (290). Thus the proximal colon, especially in its higher portion, is very distensible. For the distensibility of the gut depends upon the square or the cube of its calibre. The cæcum, having twice the calibre of the transverse colon, will have a distensibility of between four and nine times that of the latter (5). The termination of the proximal colon has been stated to be provided with a sphincter. Addison remarks that in the neighbourhood of the splenic flexure there is usually to be found a considerable diminution in the lumen of the gut with marked sacculation (2). And Rost notes the occasional occurrence of a thickening of the circular muscular coat near the commencement of the descending colon (296). In his radiographic examinations Boehm noticed a narrowing of the transverse colon usually to the right of the middle line (see p. 175). Between this site and the cæcum, the colon contained undivided contents. Beyond it the colonic mass was permanently segmented. At this point there probably start the anastaltic waves soon to be mentioned; indeed it may be at or near the site of physiological subdivision between the proximal and distal colons.

In lower animals, as in the dog, the external longitudinal coat is continuous round the whole wall (117). In human subjects this is not so obvious (166) (296) as the majority of the longitudinal fibres are massed in the three tæniæ already described. In the dog the greatest diminution in thickness of the bowel wall on distension occurs in the transverse colon and the least in the ascending colon (128).

The various movements in the proximal colon may here be noted briefly, but a full description is given in a recent article by Cannon (50). By radiographic methods the contents of the cæcum have been seen to pass onward for a short distance towards the hepatic flexure and then to return to the cæcum. This may be due simply to relaxation of the previously contracting cæcal and colonic walls, but it may be in part due to anastaltic (antiperistaltic) contractions of the transverse colon. Certainly the cæcum and adjacent ascending colon retain the bismuth shadows longer than does any other part of the bowel.

Another movement is that of local contraction in the haustra or segments whereby a small portion of the contents is pressed onward or backward for a very short distance. This is termed haustral churning, and corresponds to the segmentation movements of the small intestine. The movement which is characteristic of the proximal colon is that of anastalsis. It is the same movement as that termed peristalsis in the stomach and is really a form of segmentation. The movement has long been noted in cats, and Rieder has observed it to occur in the cæcum, ascending and transverse colons in the human subject, and more rarely in the distal colon (285).

These movements ensure the thorough mixing of food material in the colon and the opportunity for absorption of the last traces of fat, protein and carbohydrate in addition to the water (256). Anastalsis has, however, the unfortunate effect of returning food material into the proximal colon after the operation of ileo-sigmoidostomy has been performed.

If totally occluded the proximal colon becomes distended with fæcal material and will form a fistula or may even burst. Hence a fistula must always be made (256). Anastaltic movements are probably the cause of the acute dilatation of the cæcum which suddenly occurs as a complication in certain cases of cancerous stricture of the colon. In some of these cases, as Barnard said, the colon "empties back its accumulated contents and blows up the cæcum like a child's balloon" (20).

But as yet attention has not been drawn to the movements inducing onward progression of the colonic contents. They are less active at night than during the day (139). Of these the first and slower is that already mentioned as haustral segmentation. Another rests for the human colon on but two observations: those by Holzknecht and Barclay. This is known as the peristaltic rush movement. Apparently there is contraction in all the circular fibres almost simultaneously, so that the haustra disappear and the colonic contents pass with great rapidity into the distal colon (11). This movement is supposed to take place only a very few times a day.

Abnormalities in the muscular movement of the proximal colon are seen in both hypokinetic and dyskinetic types of constipation. In the former, the absence of movement results in the filling of the cæcum and ascending colon alone at the end of twenty-four hours.

But in such cases there is no actual atony, for the bismuth shadows show these portions of the colon to be no more distended than in normal cases. In the hyper-segmentation variety of dyskinetic constipation, there is well marked haustral segmentation, but apparently no progressive mass movement. More water is absorbed than under normal conditions, as is to be expected when there is retention of contents in this portion of the intestine. In the hyper-repulsion type of diskinetic constipation, there is probably an exaggerated form of anastalsis which prevents the retention in the distal colon of fæcal material until defæcation takes place. For a further account of this subject Schwarz's article should be consulted (306).

The average time taken by the passage of food material along the proximal colon is given by Hertz as four and a half hours after swallowing to reach the cæcum, six and a half the hepatic flexure, and nine the splenic flexure (139).

As the colon distends to accommodate its contents, it dilates between the layers of its mesentery or separates the peritoneum still more from underlying tissues if it have no mesentery. The arterial arcades are therefore found at some distance from the contracted bowel in order to allow for this expansion.

Dilatation of the proximal colon may occur acutely in a few hours or may be a chronic condition such as that known as congenital idiopathic dilatation, in which disease this portion alone of the bowel may be involved (117). In this last mentioned condition the muscular coat of the bowel is greatly hypertrophied in order to carry out the spasmodic efforts at peristalsis (diastalsis) which occasionally empty the gut. Thus the bowel wall may attain a thickness of 10 mm.

With reference to the serous coat of the proximal colon there is little of clinical importance to observe.

Coffey has drawn attention to the position of the organs in the abdomen, and has shown that as the

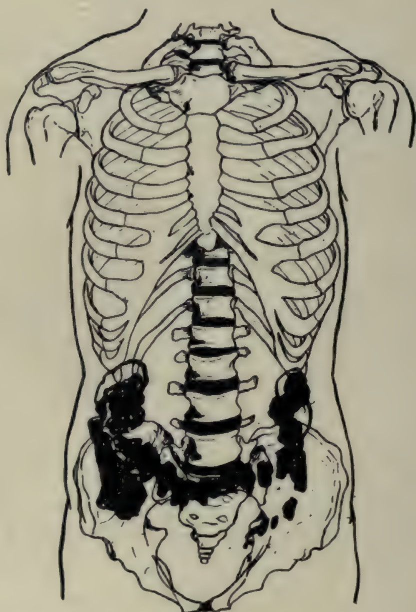


Fig. 25. Tracing from radiogram to show bismuth shadows in the proximal colon.

Individual variations occur in the site of the transverse colon, the position of which varies in the same individual from time to time. This, like corresponding variations in the precise disposition of stomach and cæcum, is what one would naturally expect. Compare with fig. 26.

ascending colon lies on the psoas at a slope of 51°, about 30 per cent. of its weight is absorbed leaving only 70 per cent. to be sustained by the tone of the abdominal musculature (62). The position of the transverse colon

n the abdomen depends largely upon the tone of its nesocolon. About this nothing is known. Smoler has lescribed what he calls ptosis of the transverse colon with consequent constipation, which was relieved by

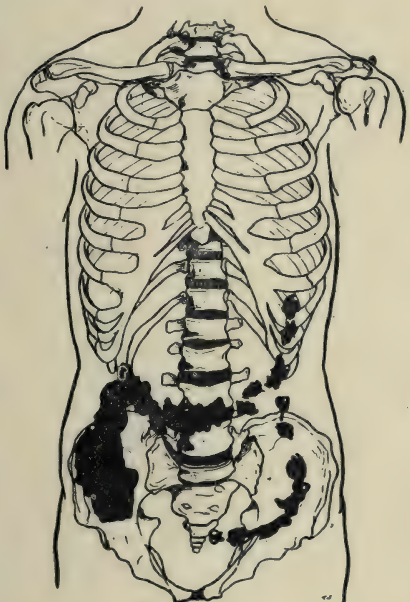


Fig. 26. Tracing from radiogram to show bismuth shadows in the proximal and distal colons.

For comparison with figs. 25, and 9, 10, 11. Note that in the distal part of the transverse colon the colonic contents are segmented completely into masses, whereas in the ascending colon this subdivision has not progressed so far.

suturing up the colon (315), but it is difficult to follow out the reasoning of the argument. As the specific gravity of all the abdominal organs with their contents is the same, and as even the splenic and hepatic flexures

surrounded by adhesions, have no delaying effect upon the passage of contents through the bowel, so-called ptosis of the transverse colon must be a condition of very dubious significance. It may be primary or may be secondary to ptosis of the stomach (118). At any rate the stomach and the transverse colon are so related that filling of the one organ has a marked influence on the position of the other, and filling of the former reflexly induces emptying of the latter.

The nervous supply of the proximal colon comes from the splanchnic nerves, which, as elsewhere, are inhibitory in function. Müller repeats that the proximal colon, as far as the hepatic flexure, is supplied by the upper splanchnic group, the cell-stations of which are in the cœliac ganglion, while the transverse colon receives splanchnic fibres from the lower splanchnic group like the distal colon (255) (see p. 199). Probably no vagal fibres reach this portion of the gut in man. Elliott and Barclay-Smith deny that the region of the colon which exhibits anastalsis receives any fibres from the sacral nerves (92). Hence the proximal colon receives no motor impulses whatever. It is, however, subject to reflex influences from many parts of the body, the stomach being one of the most important.

The blood supply of the proximal colon comes from the superior mesenteric artery. This vessel passes along the root of the mesentery to the ileo-cæcal region. In its course it gives off the middle colic branch to the transverse colon and the right colic vessel to the ascending colon. These form an arch of anastomosis, and the former also completes a second arch in the substance of the transverse mesocolon with the left colic branch of the inferior mesenteric artery, which constitutes the

supply to the distal colon. This latter arch has some importance in the performance of gastro-enterostomy (p. 155). At the ileo-cæcal region the terminal part of the superior mesenteric vessel divides into branches for the supply of the cæcum, the appendix and the last few inches of the ileum.

As in other parts of the body, the mesenteric arteries are liable to atheroma and to sclerotic processes (196), associated with which may be attacks of what is called abdominal angina.

The various branches of the artery make anastomotic loops with each other two or three cm. from the wall of the contracted bowel and in the substance of the mesocolon where it is present. The distance of these loops from the bowel wall provides a free margin of mesocolon, between the layers of which the gut may penetrate as it distends. Beyond these loops there is but little anastomosis between the vessels passing to the walls of the gut. This fact must be remembered in the performance of resection of the bowel, in which operation more gut should be cut away at the free than at the attached border in order to provide against possible gangrene (256). Occasionally an embolus enters the main vessel or one of its branches, and then infarct is likely to occur (111), for, as previously mentioned, the vessels of the intestine are, for practical purposes, end arteries.

The radicles of the superior mesenteric vein follow the same course as the corresponding arteries, but the main trunk empties directly into the portal vein. Pylephlebitis and thrombosis, spreading even to the portal junction, may result in cases of appendicitis. Braun suggests that as the ileo-cæcal vein is the one affected, it should be ligated, in view of its distribution, close to

the point where it empties into the superior mesenteric trunk, a point situated adjacent to the vertebral column (39).

The lymphatics of the proximal colon are much more numerous than those of the upper distal colon. They drain into nodes on the intestinal wall and in the appendices epiploicæ. These are known as the epicolic group. A second set of nodes found alongside the colon is termed the paracolic group. Along the course of the main arterial stems are the intermediate nodes. Lastly at the origin of the superior mesenteric artery lies the main group. One of these lies behind the third part of the duodenum, and is miscalled the "duodenal gland." This is the classification by Jamieson and Dobson. An appendicular abscess may arise around the appendix itself, or it may result from the breaking down of any one of the epicolic or paracolic nodes. Jamieson and Dobson point out that this may also occur in tuberculosis (161). The lymphatics from the appendix may drain into the so-called appendicular node, which, if present, drains varying parts of the appendix, into the nodes along the ileo-cæcal artery, or into nodes in front of and behind the cæcum.

Lockwood has frequently noticed in appendicitis the enlargement of the paracolic nodes alongside the ascending colon, a group which has come to be called Lockwood's Chain (209). This, however, does not indicate the direct route of lymphatic drainage from the appendix, but merely a collateral extension of infection. Also, according to Lockwood, there may be extension along the appendiculo-ovarian ligament if that be present. The collateral extension of inflammation along lymph channels to the pelvis has been discussed by Cohn (64).

Quenu has suggested that the presence in fulminating appendicitis of a tender area extending from the right iliac fossa upward and inward toward the middle line may be an indication of nodal enlargement (274).

For the adequate excision of the area affected in malignant disease of the cæcum, Jamieson and Dobson suggest the following order of procedure. The third part of the duodenum is exposed and the "duodenal gland" secured. The ileo-cæcal and right colic vessels are ligatured and divided half an inch from the superior mesenteric trunks to devascularise the whole of the ascending colon. Then the terminal part of the ileum, the cæcum, the ascending and part of the transverse colons are excised together with a small part of the ileal mesentery, care being taken of the right ureter, which passes behind the last-mentioned.

Corner and Sargent (71) separated volvulus of the cæcum into three varieties, of which two depend on abnormalities of the mesentery, and the third, which may be present with either of the other two, on congenital malformation of the cæcum and its mesentery.

In the first, jejuno-ileum, cæcum and a varying amount of colon have one common mesentery, the axis of rotation being practically the pedicle formed by the superior mesenteric vessels.

In the second, the root of the mesentery is not so limited as in the previous type, but the mesentery of cæcum and colon is, like that of the jejuno-ileum, longer than the mesentery of the lower ileum. This variety Corner and Sargent state to be the commonest.

The third type is a rotation of the cæcum on its own longitudinal axis, and is the variety already mentioned (see p. 163).

CHAPTER X.

The Distal Colon, Rectum and Anus.

The distal colon comprises the descending, iliac and pelvic colons, the rectum and the anal canal. It may be that differences of diet are associated with variations in the limit between the proximal and distal colons. Elliot Smith noted that in ancient Egyptian bodies the contents of the colon extended uniformly to the iliac portion, and that nodulation was present only in the pelvic segment, a condition of affairs which led Elliott and Barclay-Smith to suggest a possible extension of the proximal colon in these ancient frugivorous people (92). With the exception of the rectum and anal canal, the distal colon closely resembles the proximal colon in its gross features. Tæniæ, appendices epiploicæ and diverticula are all present. Indeed diverticula are far more abundant in the pelvic colon than elsewhere in the alimentary tract (316). Differences are found in the nerve, lymph and blood supply from the corresponding features of the proximal colon, and associated with these is a difference in function. The distal colon may be considered a storehouse for fæcal matter until a convenient opportunity occurs for defæcation. It has practically no absorptive power, and probably its secreting power is limited to the formation of mucus for the lubrication of the fæces. At autopsy it is usual to find the descending and iliac portions contracted and the pelvic segments distended to a variable degree. The length of the pelvic colon varies greatly in different subjects. Even in a

child, it may be 60 to 90 cm. long if distended or obstructed. On the other hand, even in an adult it may be less than 30 cm. long. Peritoneum usually binds the descending and iliac portions to the dorsal abdominal wall without the intervention of a mesentery.

The position occupied by the descending colon is to the lateral side of the left kidney and a little further from the middle line of the body than the ascending colon. The descending colon is mapped out on the surface of the abdomen immediately to the lateral side of the left lateral inguinal line, and extends from the intersection of the mid-axillary line and the upper border of the ninth rib marking the site of the splenic flexure, to the intertubercular plane which indicates the level of the iliac crest.

From the iliac crest the iliac colon extends to the true pelvic brim at the sacro-iliac synchondrosis, a point indicated by the junction of the upper and middle thirds of a line which joins the umbilicus with the intersection of the inguinal (Poupart's) ligament and the left lateral inguinal line. The pelvic colon which succeeds the iliac is normally about 50 cm. in length in the adult. It is equal in length to the transverse colon, and is rather longer in the male than in the female (166).

Frequently the descending and iliac colons possess no mesentery, but in 364 cases out of 982 in children, Smith noted that some part of this segment of the bowel did actually possess a mesocolon (311). The pelvic colon has a mesentery much more frequently, although where a very short pelvic colon occurs it may be absent (309). The attachment of the pelvic mesocolon to the dorsal wall runs from the left sacro-iliac synchondrosis along the brim of the true pelvis to the neighbourhood of the

sacral promontory, and then vertically downward to the third piece of the sacrum or the intervertebral disc immediately caudal to it. At this level the pelvic colon becomes rectum and the mesentery is lost. Very frequently the mesentery is simply attached along a curved line which passes between the sites of its commencement and termination, and which presents a concavity downwards. As the distance between the commencement and termination of the mesentery is only about 10 cm., this portion of the colon may be said to have a narrow pedicle. A condition of chronic inflammation may be set up and maintained in the mesentery by any source of long continued irritation, and such an inflammation is not uncommon in the pelvic mesocolon, in which case stiffness and contraction are produced, leading in many cases to narrowing of the base of attachment (20). This narrowing of the "pedicle" of the gut assists in predisposing the pelvic colon to volvulus. In three out of twenty-two autopsies Homen and Wallgren found that inflammation had caused great shrinkage in the pelvic mesocolon (154).

Immediately beneath the commencement of the pelvic mesocolon and intervening between it and the left iliac vessels there is often found a pocket of peritoneum known as the intersigmoid fossa, which may become the sac of an internal hernia. For practical purposes the "sigmoid loop" is now synonymous with the pelvic colon.

It is the pelvic colon which is utilised in the operation of left inguinal colostomy, for in many cases the iliac colon, not possessing a mesentery, cannot be raised to the level of the wound in the abdominal wall. In order to prevent prolapse of the gut it used to be the custom

to bring into the wound the highest possible loop of pelvic colon, but this procedure left only a short length of bowel beyond the splenic flexure for the collection of fæces. Hence it is now customary to fix in the wound the lowest portion possible of the pelvic colon in order to preserve the greatest amount of distal colon to act as a fæcal storehouse. Prolapse can be prevented in the low operation by fixing the bowel obliquely in the thickness of the abdominal wall as in Frank's operation for gastrostomy. If the mesocolon is too short for this, the same functional result is obtained by twisting the bowel in a half circle before bringing it into the wound (248).

In the adult the pelvic colon, if undistended, lies entirely within the pelvic fossa of the peritoneal cavity, but in the infant and the child, the pelves of whom are comparatively small, it is to a large extent an abdominal organ. In the child it frequently opens into the rectum from the right, the terminal portion of pelvic colon lying in the right half of the pelvic fossa, whereas in the adult in many cases the pelvic colon opens into the rectum from the left. The disposition of the pelvic colon in the pelvis of the adult is first from left to right and then from right to left, so that the terminal portion forms an acute angle with the upper part of the rectum. In consequence of this arrangement a valvular fold of the mucosa projects into the lumen of the gut on the ventral and left aspect at the pelvi-rectal junction. The presence of this fold necessitates the turning of the sigmoidoscope to the right before it can slip round into the pelvic colon. This is not invariably the disposition of the bowel even in adults. Sometimes it is necessary to turn the sigmoidoscope to the left to enable it to enter the pelvic colon. It is possible that some sphincteric action may

take place at the pelvi-rectal junction (256) (268), although the presence of a definite anatomical sphincter is denied by Symington (321). The pelvic colon is distensible to an even greater degree than the transverse colon or the cæcum. It is the portion of gut most subject to volvulus. In acute volvulus the increase in size of the pelvic colon may be so great as to cause very considerable distension of the abdomen in a few hours.

Recently Gysi has collected a number of cases of variation in position and course of the pelvic colon, and to these he has added others which came under his own observation (121).

Hirschsprung's disease, or chronic distension of the colon, may affect either the proximal or distal segment or both. It is of obscure origin and develops in early life. For a summary of the suggested causes Meyer's paper may be consulted (235). The condition is said to be more obvious radiographically if the bowel is inflated with gas through the anus (105). Children in whom this anomaly is present do not invariably die, and those who live, possess what in later life is termed a megasigmoid (218). Huge dilatation of the colon is seen in some cases of acromegaly. Occasionally Hirschsprung's disease affects part of the distal colon only, as in Bard's (16) and Barclay-Smith's cases (15), in which the anomaly was confined to the rectum and pelvic colon. In some of these cases the hypertrophied longitudinal muscular coat is visible even macroscopically over most of the surface of the bowel (279). According to Geddes some are associated with what he describes as enlargement of the abdominal sympathetic system (108).

The distal colon is the part of the bowel in which embryonic differentiation and growth is latest and

slowest. When the fœtal duodenum is 100 μ in diameter, the splenic flexure also has a diameter of 100 μ (322). In some instances the distal colon never develops, and the gut is permanently occluded from the region of the splenic flexure onwards.

The wall of the distal colon presents no marked differences in its anatomical features from that of the proximal colon, and the characteristic movements are the same. Cannon describes two methods of emptying of the distal colon, the rapid mass movement and the slow progressive movement of small fragments, both movements being similar to the corresponding ones in the proximal colon (50). There is probably also a superficial wave of contraction for the onward propulsion of accumulated gas (28), which is accompanied by small crackling sounds (48). Hertz found that the whole of the distal colon from the splenic flexure onward is emptied in defæcation (139). But Schwarz has observed even part of the ascending colon to be emptied also. This accounts for the soft nature of the last portion of a large fæcal discharge (307). The accumulation of waste material stops at the pelvi-rectal junction. When it becomes distended, the pelvic colon erects itself on the rectum and some of its contents pass into the latter organ thereby stimulating the desire to defæcate. In defæcation there may even be some invagination of the pelvic colon into the rectum (107). Until recently it was said that anastalsis never occurs in the distal colon. Roith now brings forward evidence to show that anastalsis may occur in the pelvic colon, though he denies its occurrence in the descending and the distal part of the transverse colon (291). The observations of Schwarz confirm Roith's statement of the occurrence of anastalsis

in the distal colon (306), an action also induced by the withholding of a stool (255). The length of time taken by food in passing through the distal colon is comparatively great. Bismuth reaches the splenic flexure nine

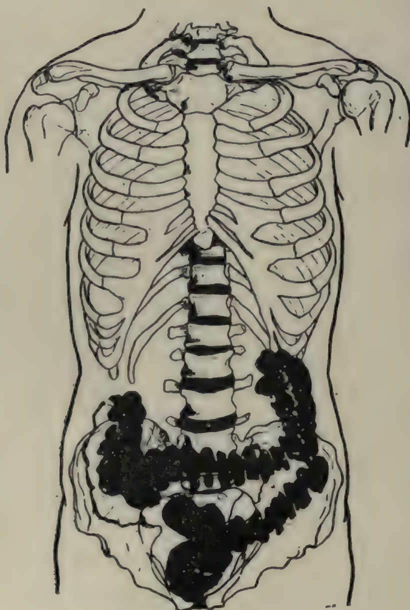


Fig. 27. Tracing from radiogram to show the course of the colon. Observe that the "kink" at the splenic flexure is for the greater part an illusion produced by the Röntgen rays passing through the body in the dorsi-ventral direction. Seen from the side both the hepatic and splenic flexures are gentle curves of bowel, not acute bends.

hours after the meal. It appears in the iliac colon at the end of eleven hours, in the pelvic colon in twelve hours and in the rectum in eighteen hours (139).

The arterial supply of the distal colon comes from the

inferior mesenteric branch of the abdominal aorta. This vessel sends the left colic artery upward, medial to the hilum of the left kidney, for the supply of the descending colon. It finally anastomoses with the left branch of the middle colic artery. The main vessel distributes the sigmoid branches, usually two in number (353) to the iliac and pelvic colons, and then continues down the root of the pelvic mesocolon to become the superior hæmorrhoidal artery for the supply of the rectum. The superior hæmorrhoidal, sigmoid and left colic vessels exhibit a series of anastomotic loops beyond which, as in the proximal colon, there is practically no anastomosis between the arterial branches. In the pelvic mesocolon the anastomotic loops lie very near the mesenteric root, and are further removed from the contracted bowel wall than the corresponding loops in any other portion of the gut; a fact which is to be associated with the great distensibility of the pelvic colon. The lowest of these loops unites the distal sigmoid vessel with the superior hæmorrhoidal artery, and as a rule the anastomotic branch joins the latter vessel about 1·5 cm. below the sacral promontory. This is a point of great importance in excision of the rectum (327), and is known as Hartmann's critical point (127). If, in operation by the perineal route, the superior hæmorrhoidal artery is ligatured below the point at which it receives the anastomotic branch, the whole of the blood supply will be cut off from the area of bowel which is supplied by the superior hæmorrhoidal artery. If the ligature is placed on the superior hæmorrhoidal vessel above the entry of the anastomotic branch, there is no danger of gangrene to the bowel since blood flows through the anastomotic vessel to the superior hæmorrhoidal and so to the gut,

while, during the operation and until the anastomotic branch enlarges sufficiently, the area of operation is comparatively bloodless. A full discussion of the point together with the best methods of dealing with the problems raised by carcinoma recti will be found in the article just mentioned (327).

The inferior mesenteric vein receives the venous drainage of the whole of the distal colon except the anal canal. This vessel, which is the continuation of the superior hæmorrhoidal vein, passes upward alongside the left colic artery behind the peritoneum and medial to the hilum of the left kidney to reach the splenic vein, which is a tributary of the portal.

Medial to the kidney the inferior mesenteric vein and the left colic artery form the vascular arch of Treitz, which may be related to retroperitoneal hernia (see p. 123). In the adult the inferior mesenteric vein possesses either no valves or very incompetent ones (346), a fact which is of importance in relation to hæmorrhoids.

The lymphatics of the descending and iliac colons are less numerous than those from the remainder of the large bowel (272). On the other hand, the pelvic colon is richly supplied with lymphatics. The distribution of lymphatic nodes to the distal colon is on precisely the same plan as in the case of the proximal colon (see p. 188).

The nerves to the distal colon are derived from the splanchnics and the second, third and fourth sacral nerves. The latter do not pass direct to the bowel wall, but have intermediate ganglia on their course. Probably they terminate in the isolated nerve-endings to be found in the distal colon, and do not join the splanchnic plexus in the muscular coat (48). In this respect they resemble

the vagus nerves in the stomach and small intestine. Their function is similar to that of the vagus in the alimentary tract, namely, to keep up tone and enable diastaltic movements to occur. The splanchnic nerves are, as usual, inhibitory in function, and as suggested

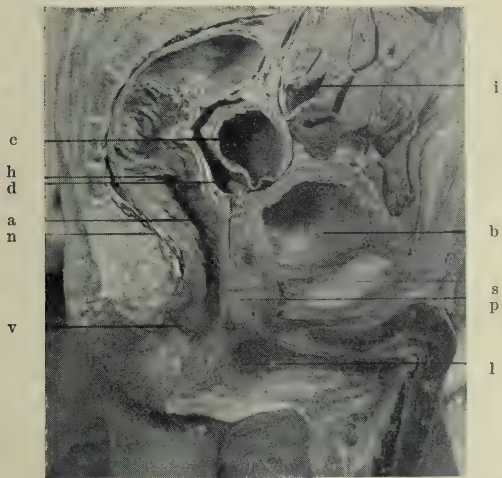


Fig. 28. Photograph of dorsi-ventral median section of male pelvis to show the level of the great valve of Houston and the rectal relations. For comparison with fig. 29.

a, ampulla ; b, bladder ; c, pelvic colon ; d, pouch of Douglas ; h, great valve of Houston ; i, ileum ; l, bulb of penis ; n, levator ani ; p, prostate ; s, pubic symphysis ; v, line of anal valves.

by Müller, they probably originate from the lower splanchnic group of cell stations, which are located in the inferior mesenteric ganglion (255).

The Rectum.

The rectum is the terminal dilated portion of the distal colon and communicates with the exterior by means of the anal canal. It possesses no mesentery and is but

partially surrounded by peritoneum even in its upper part, which is termed the pelvic chamber. The lower portion lies beneath the level of the peritoneum, but above the levatores ani, and is called the ampulla. The reasons for this nomenclature will be apparent later (see p. 211). The anal canal is a constricted passage below the levatores ani, about 3 cm. in length, by which the rectum opens into the anal fissure between the buttocks. It is the portion which grips the finger in a digital examination.

After passing through the anal canal, the finger enters the dilated ampulla and then reaches a fold of mucosa which partially subdivides the rectum. This fold is the third or great valve of Houston: it involves the ventral wall of the bowel and extends as a rule more to the right than to the left. It marks the subdivision between the pelvic chamber and ampulla, and approximately indicates the lowest level of the peritoneal cavity, namely, the bottom of the pouch of Douglas. With the aid of the sigmoidoscope other transverse folds are to be seen above the one just mentioned. They are variable in number and their presence depends upon distension of the organ. In the fœtus the uppermost projects from the right wall because the pelvic colon opens into the rectum from the right (see p. 193). In sigmoidoscopic examination of the adult, the instrument has usually to be passed to the right before the pelvic colon can be entered, as in the adult the pelvic colon enters the rectum from the left and this causes the valvular fold to involve the left wall (89). The pelvi-rectal fold, like the great valve of Houston, involves the ventral wall of the bowel and extends laterally. It may be so pronounced that the opening from colon to rectum is exceedingly difficult to trace.

In such a case the pelvi-rectal orifice is found ventrally and low down (257). The method of production of the so-called pelvi-rectal valve has already been indicated. There is no doubt that the presence of the great valve is associated with the fact that the capacious rectum possessing no mesentery is bound directly to the concave sacrum, which disposition is in itself sufficient to produce a kink in the ventral wall. The presence in the adult of the terminal portion of pelvic colon in the left side of the pelvic cavity causes the pelvic chamber of the rectum to lie somewhat to the right of the middle line, and thus the great valve involves a greater extent of the right rectal wall than the left. In the fœtus, child and adult female, the sacral concavity is less marked than in the adult male. Hence the rectum follows a straighter course. It is noteworthy that it is in women and children that rectal prolapse most frequently occurs (see p. 211).

In the normal individual the rectum contains fæcal matter only when there is the desire to defæcate, but the pelvic chamber and even the ampulla may be found choked with fæces in constipated persons. Frequently the ampulla contains gas. On distension of the rectum the folds already mentioned become more pronounced, and others, believed to be compensatory in nature, appear on the opposite wall. When distended with gas the rectum is said to be ballooned, a condition dependent for its production upon spasm of the sphincters, which normally alternate in rhythmic manner between contraction and relaxation. The spasm is caused by irritation in the distal colon, and is not characteristic of malignant growth. Any catarrhal state of the rectum or pelvic colon will produce ballooning, and it is especially

common in atrophic catarrhal proctitis or sigmoiditis (257). On the other hand, relaxation of the sphincters becomes a chronic condition in old age. Therefore in elderly people an anal canal can hardly be said to exist. But in the young healthy adult man, it is about 3 cm. in length; in women its length is about 2 cm. (9). The anus is an indefinite site, but may be said to represent the junction of skin with mucous membrane. The distance from the anus to the great valve of Houston is about 8 cm. and to the pelvi-rectal valve about 13 cm. The junction of rectum and anal canal lies about 2·5 cm. below and in front of the tip of the coccyx. While the axis of the rectal ampulla is directed ventrally and downward, that of the anal canal passes downward and dorsally, almost at a right angle with the former.

The mucosa of the rectum proper is red and vascular; that of the anal canal is paler. Scattered over the surface of the rectum are numerous little depressions known as rectal pits, at the bottom of each of which lies a submerged nodule of lymphoid tissue. Far more numerous than these, so plentiful indeed that they give the mucosa a sieve-like appearance when examined with a hand-lens, are the Lieberkuhn's follicles, which secrete mucus for the lubrication of the fæces. In proctitis and sigmoiditis the mucosa is covered with an exuberant and sticky secretion of white granular mucus, excess of which occasionally gives rise to an intractable form of pruritus (257). In the pelvic chamber, the rugæ of the mucosa are transverse like those of the pelvic colon. In the ampulla the rugæ are vertical, and are produced by vessels lying in the bowel wall (351). These vertical rugæ are continued down to the muco-cutaneous junction, which lies about half the distance along the anal

canal, and are called the columns of Morgagni. They are about five in number (89), and their distal extremities are united by folds of mucosa, the remnants of a proctodœal hymen, known as anal valves. Frequently small tags of tissue are found on these valves or on the columns near the valves. Such tags are known as papillæ of Morgagni. Between the columns and above the valves are the lacunæ of Morgagni, little pouches where fæcal matter may lodge and form the starting point of a fistula or a fissure. The muco-cutaneous junction exhibits a white band known as the white line of Hilton. To this band is also given the name of the pectinate line, for the anal valves with the distal extremities of the columns present the appearance of a series of fans. On the cutaneous surface of the anal valves are numerous puckers of skin produced by the action of the external sphincter. If these become inflamed and œdematous, they form one variety of external piles, which later will subside into tags of skin around the anus (89). Sometimes the mucosa of the ampulla presents a diverticulum in the middle line dorsally (9) or ventrally. In any case, in women especially, a pocket of the entire thickness of the rectal wall is liable to develop in the mid-ventral line at the lowest part of the ampulla immediately above the levatores ani.

The muscular coat of the rectum consists of external longitudinal and internal circular layers, of which the former is distributed evenly around the rectal wall and not massed into tæniæ as in the colon. The circular coat is thickened in the region of the great valve of Houston, and again in the upper half of the anal canal to form the internal sphincter, and through it at various levels pass the vessels of supply. It is possible that the

effect upon the veins of contraction of muscular fibres may assist in the production of hæmorrhoids. The fibres of the levatores ani mingle with those of the musculature of the anal canal. Certain of the longitudinal fibres from the ventral aspect of the ampulla and the anal canal pass to the membranous urethra and the dorsal aspect of the prostate gland. These represent the wall of the original communication between the rectum and the urogenital sinus. The ventral median pocket of mucosa already mentioned also represents this communication, which is complete in cases of congenital recto-urethral fistula.

The external sphincter is situated around the distal half of the anal canal, which is lined with cutaneous epithelium. A common form of fistula passes between the external and internal sphincters. It has its internal opening in the region of the lacunæ of Morgagni, and it opens externally on the skin of the buttock wide of the external sphincters.

In the adult male the peritoneal coat extends on the ventral aspect of the rectum to the neighbourhood of the great valve of Houston (351), about 8 cm. from the anus. It only partially covers the lateral walls of the pelvic chamber, and does not cover the dorsal wall at all. Thus the line of peritoneal reflexion passes downward and ventrally on the wall of the pelvic chamber from the pelvi-rectal junction to its distal limit at the level of the great valve of Houston. Along this line of reflexion runs the main branch of bifurcation of the superior hæmorrhoidal artery. Distension of the rectum raises the level of the lowest limit of the peritoneum. In the woman and the child the peritoneum reaches a somewhat lower level than in the adult man, and covers the front

of the proximal portion of the ampulla. In the earlier months of fœtal life the peritoneum ensheathes the ventral aspect of the whole of the rectum to the upper surface of the levatores ani and the perineal body (93). As the peritoneum in front of the pelvic chamber forms the dorsal wall of the pouch of Douglas, an inflammatory deposit occurring there in such a disease as appendicitis can readily be palpated by rectal examination. Sometimes cancerous deposits secondary to carcinoma in other regions of the abdomen (*e.g.*, the stomach) (see p. 23) occur in the pouch of Douglas. Frequently they are surrounded by a mass of inflammatory tissue.

The arterial supply of the rectum and anal canal arises from the hæmorrhoidal vessels. Of these the inferior hæmorrhoidal branch of the internal pudic artery supplies the anal canal distal to the white line, the middle hæmorrhoidal branch of the internal iliac trunk runs to the region of the white line and anal valves, while the superior hæmorrhoidal artery, which is the continuation of the inferior mesenteric, distributes branches to the pelvic chamber and ampulla. The last mentioned vessel reaches the dorsal aspect of the pelvi-rectal junction by passing downward in the root of the pelvic mesocolon. It then subdivides and its two branches of bifurcation pass as already indicated along the lines of peritoneal reflexion, distributing many vascular twigs as they proceed. Its relation to the operation of excision of the rectum by the perineal route has already been discussed (see p. 197). There is a free anastomosis between the several arteries of supply to the rectum and anal canal.

The veins of the rectum and anal canal have a similar distribution to that of the arteries, and free anastomosis

exists also among the veins. The superior hæmorrhoidal vein continued upward becomes the inferior mesenteric, which joins the splenic vein, a tributary of the portal. The middle hæmorrhoidal vein throws its blood into the internal iliac, and the inferior hæmorrhoidal is a tributary of the internal pudic, which joins the internal iliac. The inferior and middle hæmorrhoidal veins form part of the systemic circulation, and the superior hæmorrhoidal drains into the portal system. The free anastomosis between the veins of the rectum and anal canal results therefore in the communication between these two great venous systems, and a condition is produced similar to that at the cardiac orifice of the stomach. In portal back pressure, either general or local, the venous anastomosis of the anal canal is engorged owing to the increased drainage into the systemic circulation, and there results a condition of varix or internal hæmorrhoids, which is intensified by the passage of the veins through the muscular coat. Besides an arterial twig, each column of Morgagni contains a moniliform venous channel, which on engorgement projects as a pile. When such a condition develops, one hæmorrhoid, known as the perineal pile, is frequently found on the ventral aspect of the anal canal, and two others are placed laterally one to the right and one to the left. Smaller hæmorrhoids may exist between these larger ones (89). In Whitehead's operation the mucosa of the proximal portion of the anal canal, above the white line, is removed along with its contained venous plexus, but the muscular coat and skin must not be interfered with lest incontinence or stricture follow.

Like the blood vessels, the lymphatics of the rectum and anal canal may be divided into three areas. Those

of the pelvic chamber and ampulla pass to nodes placed on the lateral walls of the rectum and in the substance of the pelvic mesocolon alongside the superior hæmorrhoidal artery. They have no clinical association with the lymphatics of the pelvic colon itself (313). The lymphatics of the anal canal pass to the nodes along the internal iliac vessels. Some run alongside the middle hæmorrhoidal artery while others drain through the fatty tissue of the ischio-rectal fossa to reach the same destination. These travel in the direction taken by the inferior hæmorrhoidal artery, but do not slavishly follow the vessel.

The lymphatics of the skin around the anus drain into the inguinal group of nodes in common with the rest of the perineal vessels (272). All these vessels communicate in the wall of the gut. But there is no clinical communication between the rectal lymphatics and the sacral nodes, between which and the pararectal nodes on the wall of the rectum lies the fascia propria of Waldeyer (327).

The nerve supply of the rectum and anal canal comes from the splanchnics and from the nervi erigentes of the third and fourth sacral nerves. The latter pass in a leash from the sacral foramina to the lateral aspect of the ampulla where they penetrate the rectal wall. These, together with the middle hæmorrhoidal vessels and the surrounding connective tissue, constitute the rectal stalks (*les ailerons*) and form a considerable support to the viscus. Secondary nodules occurring in the sacrum as metastases in carcinoma recti have found their way to the bone along the rectal stalks. It is only when these are severed that the organ can be drawn down and the pelvic colon sutured into the anus without tension (314).

Cutaneous sensation can be perceived for about 3 cm. above the line of the anal valves. Should an abrasion or fissure occur in this situation, intense pain is the result. After perineal excision of the rectum, as after the operation of colostomy, cutaneous sensation is ultimately developed in the two or three cm. of bowel adjacent to the skin surface to which the bowel has been sutured.

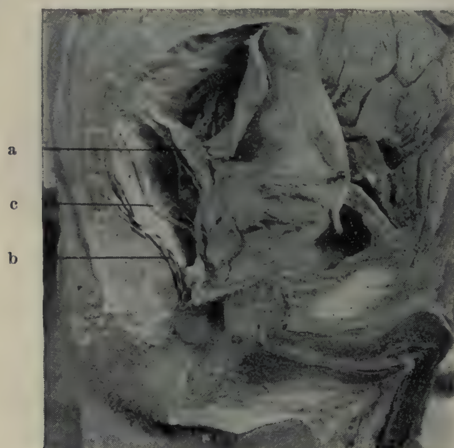


Fig. 29. Photograph of the pelvis represented in fig. 28 with the rectum drawn aside to to expose the combined rectal fascia and stalk (a), the levator ani (b), and the nerve to the levator ani (c).

On each side of the anal canal below the level of the levatores ani is the fatty tissue of the ischio-rectal fossa, which is subdivided into upper and lower compartments by a fascial sheet passing from Alcock's canal (fascia lunata) medially to the wall of the gut (93). It is in the lower of these subdivisions that ischio-rectal abscess

occurs. The passage of lymphatics from the anal canal through the tissue of the ischio-rectal fossa determines a worse prognosis for carcinoma recti starting in the anal canal than in any other part of the viscus. Above the levator ani and between it and the peritoneum is an interval called by Richet the superior pelvi-rectal space (89) in which lies the rectal stalk already mentioned (p. 207), one of the main and indeed ultimate supports of the rectum.

As already mentioned, the rectal stalks consist of the perineural tissue surrounding the branches of the nervi erigentes which enter the rectum at the lower part of the ampulla and the perivascular tissue which envelopes the middle hæmorrhoidal artery. In excision of the rectum, after the levatores ani have been severed, these stalks must be dealt with before the gut can be drawn down (327).

In the hollow of the sacrum and forming for the rectum a dorsal sheath whose lateral extremities are constituted by the rectal stalks is the fascia propria of Waldeyer (337), or the rectal fascia of J. W. Smith (313) (314). This is merely the connective tissue filling the interval between the rectum and pararectal nodes and the sacrum and sacral nodes, but clinically it forms a barrier effective in most cases against the transmission of carcinomatous metastases from the viscus to the sacral nodes. As a rule it can be torn through easily with the finger at operation, and thus differs from the powerful rectal stalks. It is loosely attached to the ventral aspect of the sacrum at the level of the third piece. The rectal stalks may be severed at operation without interference with the branches of the nervi erigentes which pass to the urino-genital tract (327).

Fig. 30. Drawing of dorsi-ventral median section of male pelvis. The individual from whom this drawing was made died from carcinoma recti. The figure illustrates the function of rectal fascia in making the rectum a "self-contained" organ, in other words, in effectively separating the rectum and pararectal lymphatic nodes from the sacrum and sacral nodes.

a, site of carcinoma in rectum; b, pouch of Douglas; c, bladder; d, seminal vesicle; e, prostate; f, bulb of penis; g, fistulous ulcer; h, levator ani; i, rectosacral aponeurosis; j, carcinomatous pararectal gland. It is to be noted that though the infected gland shown in the figure lies just above the levator ani, it is separated from the latter by the rectosacral aponeurosis. This fascial sheath for the rectum and pararectal glands is very well marked in the specimen from which the drawing was made and shows clearly its attachment to the sacrum. The only successful manner of taking out rectum and pararectal glands in one piece is to dissect from below, passing the hand between levator ani and rectosacral aponeurosis and next between the latter and the sacrum. The numerous sacral attachments of the aponeurosis render it impossible satisfactorily to perform this manoeuvre from above. The muscle and aponeurosis lie in immediate relation with each other in the present case, but could easily be separated.

It will be observed that the rectum bears a very intimate relation to surrounding fascial tissue. Cripps thus explains the liability to pelvic cellulitis and the subsequent contraction which produces so inveterate a type of rectal stricture. The basis of Mummery's operation for rectal prolapse in adults is the replacement of the cellular tissue in the rectosacral interval by cicatricial scar tissue (258).

Most of the types of rectal prolapse or procidentia are really cases of rectal intussusception. The only true prolapse is that variety which starts at the anal margin. In connection with the occurrence of this condition in young children it is worth noting that in infants at birth the rectal stalks are approximately the same in proportionate length and extensibility as in the adult, that there is none of the so-called laxity of the stalks, but that the rectum is already a pelvic organ, and in view of its low position relative to the bladder and in females to the uterus, and the fact that it is not shielded by an overhanging sacral promontory, it is, in early life, in a position of mechanical disadvantage (328).

The similarity in many ways between the pelvic chamber of the rectum and the pelvic colon has led Wood Jones to include it with the latter in the hindgut. In some cases of imperforate rectum, this is the only portion developed. It is the old rectum so to speak which originally opened into the urino-genital sinus. According to Wood Jones, the portion here termed the ampulla and the upper part of the anal canal as far as the white line, are developed from the post-allantoic gut, and form a new development which serves to carry the hind gut from its original cloacal opening to a new perineal outlet. He points out that morphologically the part of the anal

canal which lies above the anal valves belongs to the ampulla and therefore he adheres to the alternative nomenclature which includes ampulla and upper anal canal as the perineal chamber (351). As this term is not a good one for clinical purposes, the subdivision into ampulla and anal canal has been retained in the present description. The lower portion of the anal canal forms what Wood Jones defines as the anus proper. It corresponds to the original proctodœal ingrowth and extends as high as the level of the anal valves (351), which, originally a kind of rectal hymen, are best marked in the fœtus and child. According to Wood Jones' description, if the post-allantoic gut does not develop, the rectum ends blindly comparatively high up in the pelvis, or may terminate by joining the urethra in the male, or the vagina in the female to form a congenital recto-urethral or recto-vaginal fistula. The proctodœal dimple may or may not develop in these cases. If it does develop, the septum between the post-allantoic gut and the proctodœum may not break down. Or the lower end of the pelvic chamber may be connected with the proctodœal ingrowth by a solid cord of tissue. Lastly the post-allantoic gut may develop too far, and in such cases the ampulla exhibits an appendix-like diverticulum in the median line of its dorsal wall (351) (p. 203). Rarely in cases of imperforate rectum, this backward growth forms a fistula on the buttock through an aperture in the sacrum. On the other hand it must be remembered that Frank held strongly that congenital occlusion of the rectum is not to be considered as a malformation due to arrested development, but to an abnormal fusion caused by excessive overgrowth of bowel tissues during the third or fourth month of fœtal life (106).

CHAPTER XI.

Liver, Gall Bladder, Pancreas.

I. The Liver.

The liver lies beneath the right cupola and part of the left cupola of the diaphragm.

Of its two lobes the right is much larger than the left.

It is said that a septum occurs between the two lobes, and that the branches of the portal vein, which supply the right and left lobes, do not communicate across this septum (215). In any case cirrhosis of the organ usually causes enlargement of the right lobe only, while in Hanot's cirrhosis the left lobe is also enlarged. Sérégé suggested that the right lobe is more intimately associated with the venous return from the alimentary canal, while the left lobe has more definite association with the spleen (308), but this interpretation has been shown by Looten to be erroneous (215).

The position of the liver differs somewhat in the erect and the horizontal positions. In either case the upper limit of the organ is indicated by the level of the diaphragm, and therefore corresponds in surface-marking to the limits already given for that structure (see p. 9). In the horizontal position the upper limit of the liver is sufficiently accurately given by the following points :

Intersection of the right lateral inguinal line with the fourth intercostal space.

Intersection of the middle line with the xiphi-sternal line.

Intersection of the left lateral inguinal line with the fifth intercostal space.

Frequently the liver does not reach quite so far to the left as the lateral inguinal line but terminates in the region of the apex of the heart. The lower margin of the left lobe of the liver is indicated by a line joining the left lateral inguinal line to the middle line at its intersection with Addison's plane. The lower border of the right lobe passes from this point along Addison's plane to the right costal margin, where it curves downward to reach its limit 2·5 cm. below the lowest point of the tenth costal cartilage, which lies in the neighbourhood of the mid-axillary line. The right lobe sometimes extends lower than the limit indicated. It may have projecting downward even into the right iliac fossa a tongue-shaped process, which is known as Riedel's lobe, and which is frequently associated with the presence of gall stones (287).

Sometimes Riedel's lobe does not project downward into the iliac fossa, but takes the same direction as an enlarging gall bladder (136). In such a case it is held up by the transverse colon and mesocolon (see p. 219).

The blood supply of the liver comes from the portal vein and the hepatic artery, which enter the organ at the hilum on its visceral or inferior aspect. Together with the bile passages, these vessels form the hepatic pedicle, the influence of which in supporting the duodenum at the junction of its first and second portions is referred to elsewhere. Sometimes two hepatic vessels are present, the additional one arising at the same point as the normal one from the cœliac axis and sometimes from the same trunk at a higher level (96).

Although there is no direct anastomosis between the

portal systems of the right and left lobes, yet according to Looten (215) there does not exist in the portal vein a double blood current as Sérégé suggested (308).

Presence of ascites in the later stages of cirrhosis of the liver has led to an attempt to divert part of the blood stream from the portal area to the systemic circulation. To this end the omentum has been implanted into the abdominal wall (Schiassi), or the peritoneal surfaces of liver and spleen have been rubbed with gauze to excite traumatic inflammation with consequent adhesions to the adjacent abdominal wall (Talma, Lens, Morison).

In one of these ways it is hoped to produce anastomosis between the portal circulation in the omentum or liver and the systemic circulation in the abdominal wall. It is probable, however, that the portal blood is not diverted to any great extent. Moreover, it is most likely that the ascites is due to a toxæmic condition. The good results obtained by the Talma-Morison method have been explained in the following manner:—

(1) As the blood passing through the liver is somewhat diminished, the organ is enabled to deal more satisfactorily with that which does pass through it and so to reduce the toxæmic condition of the blood, which is probably the important factor in producing ascites. (2) The presence of vascular adhesions allows a freer supply of arterial blood to reach the liver. The nutrition of the liver cells is thus improved and they are placed under better conditions for undergoing compensatory hypertrophy (Rolleston and Turner) (294).

Macleod and Pearce (224) have shown experimentally that there is a reciprocity between the blood flow in the portal vein and the hepatic artery. Thus if the hepatic flow be diminished, an increased amount of blood passes

along the portal channels. Probably this is due to relaxation of the portal branches in the liver. Similarly Burton-Opitz stated that diminished flow through the portal channels results in passage of an increased amount of blood through the hepatic artery. Even if this be true in normal cases, it would not necessarily hold good in cirrhosis, because the interlobular connective tissue may not be loose enough to permit dilatation of the capillaries of the hepatic artery.

The disposition of the peritoneum in relation to the liver is described in Chapter III. Very little need be added at this juncture.

It is convenient to notice that the liver is fixed to the ventral abdominal wall by the falciform ligament whose position is mapped out on the surface by a straight line extending from the xiphi-sternal junction to the umbilicus.

This ligament may be bulged to one or other side by the presence of an abscess in the right or left subphrenic pouch of peritoneum.

The peritoneum leaves uncovered and in apposition with the diaphragm a portion of the liver known as the *bare area,* which lies to the right of the vena cava on the dorsal aspect of the organ. Pus from the substance of the liver itself, as in hepatic abscess, may form a subphrenic collection in the bare area. Hence in addition to the intra-peritoneal subdiaphragmatic areas already mentioned (see Ch. III), there must be added a fifth. It is known as the right extra-peritoneal subphrenic area (18).

II. The Gall Bladder.

The gall bladder is situated on the visceral aspect of the liver to the right of the quadrate lobe and between the ventral border of the liver and the transverse fissure.

Occasionally it is embedded in the substance of the organ (175), or it may be absent (239). Of pyriform or cylindrical shape, it is divided into a fundus or rounded

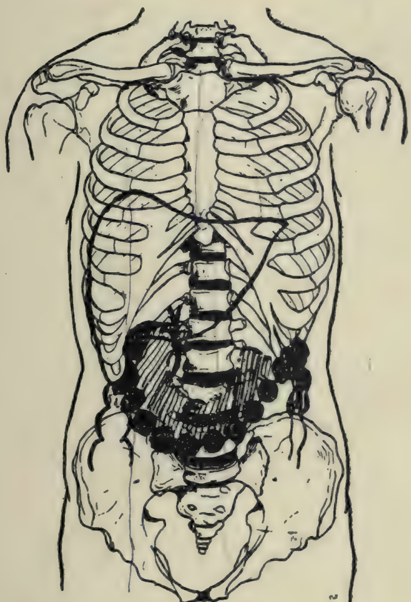


Fig. 31. Approximate surface topography of the gall bladder and bile ducts in the cadaver.

The position of the duodenum has been indicated by broken outlines. Note that the junction of the cystic and hepatic ducts lies behind and not above the first part of the duodenum. The transverse colon is inserted to show how that organ with its mesentery directs the enlarging gall bladder toward the neighbourhood of the umbilicus.

extremity, a body or main part with upper and lower aspects, and a neck, which is continuous with the cystic duct. Its direction is from before backward, upward and

to the *left,* so that while the fundus lies 10–12 cm. from the middle line, the neck is only 3-5 cm. therefrom.

The gall bladder is 8–10 cm. in length, 3 cm. in breadth, and its capacity equals 30 cc. (58).

As a puncture in the wall of the gall bladder tends to remain open, it is not advisable to pass an exploratory needle through the abdominal wall into the organ for diagnostic purposes.

In the child the fundus of the gall bladder lies entirely beneath the liver in the margin of which there is no cystic notch. As the child grows, the fundus extends beyond the liver margin and the cystic notch appears. In the adult the fundus passes beyond the liver margin for a distance of 2-4 cm. according to the state of distension of the gall bladder (58). The fundus is entirely covered by peritoneum.

The body of the gall bladder is bound down to the liver by intervening cellular tissue, through which pass the lesser cystic vessels from the liver. Hence peritoneum covers its lower surface only. Sometimes, however, the body is suspended from the liver by a mesentery (109). The cystocolic ligament, an outlying part of the lesser omentum (see p. 122), is present in one subject out of four, and passes from the under surface of the gall bladder to the second part of the duodenum and the adjacent transverse colon.

The clinical importance of this ligament lies in the fact that it forms a focus for adhesions binding gall bladder to duodenum or transverse colon, and thus permitting gall stones to ulcerate through into one or other of these viscera.

The relation of the gall bladder to the transverse colon is again important in that cholecystitis may be associated

with obstinate constipation, owing to paralysis of the large bowel through its contact with the inflamed organ (287).

The green discolouration of the pyloric canal, sometimes seen at autopsy, is due to the fact that the gall bladder not infrequently lies in close relation with it. Adhesions may develop between the gall bladder and the pyloric canal and gall stones may ulcerate through into the stomach and be vomited.

In marking out the gall bladder on the abdominal surface, the following facts are of importance. Carmichael observed that the position of the fundus of the gall bladder varies much more in the vertical than in the horizontal direction (54), but usually it lies immediately below and to the left of the intersection of Addison's plane with the right lateral inguinal line. This corresponds to the angle between the right costal margin and the lateral border of the right rectus muscle. The neck of the gall bladder lies just above Addison's plane, 3-5 cm. to the right of the middle line.

When chronically enlarged, the gall bladder forms a tumour whose line of extension is downward and toward the middle line about the umbilicus. This direction is taken because the gall bladder rests upon the upper surface of the transverse colon and mesocolon, which form a shelf for the organ. On the other hand, the acutely distended gall bladder usually enlarges upward and inward in the region of the neck (263).

In cases of gall stones, the associated inflammatory condition produces adhesions to surrounding organs and fibrosis of the gall bladder wall with consequent contraction. Chronic enlargement of the gall bladder is far more characteristic of malignant disease, especially if

jaundice also be present, than of the presence of gall stones (287).

Distension of the gall-bladder associated with jaundice may, however, occur as a result of the presence of a stone in the common duct (287).

The gall bladder is normally situated deeply in the abdomen, but may be brought two or three inches nearer the surface by placing a sand pillow under the patient's dorso-lumbar region (Mayo Robson). More room may also be gained by tilting up the head of the operating-table (248).

The neck of the gall bladder forms an acute angle with the body of the organ and lies immediately to the left of the latter. Its direction is upward and forward. It has a second acute angle with the cystic duct, whose direction is parallel with that of the body of the gall bladder. These three portions of the bile system form a Z-shaped figure. At each bend is a reduplication of mucous membrane to form a valve-like structure. Besides these folds there are several partial foldings of mucous membrane in the neck of the gall bladder. The presence of these folds renders very difficult the passage of a probe from the gall bladder into the cystic duct. The length of the neck of the gall bladder is 15–30 mm., and its diameter 7-8 mm. (58). Diverticula are frequent at the junction of the body and neck of the gall bladder. One which is often present is called Hartmann's pouch. This is a frequent starting-place for the formation of a gall stone.

The cystic duct is the narrowest portion of the bile passages. Its length is 3-4 cm., and its diameter 2-3 mm. (58). It passes upward and to the left, but turns downward when it meets the hepatic duct. The two ducts run together in a common fascia for one or two cm. before

they finally join to form the common duct. Hence a stone in the terminal part of the cystic duct will obliterate the hepatic duct also, and thus give rise to symptoms of obstruction in the common duct. The cystic and hepatic ducts lie in the right free margin of the lesser omentum in front of the foramen of Winslow. They finally join to form the common duct behind the first part of the duodenum (58).

The hepatic duct is formed in the hilum of the liver by the union of the right and left hepatic ducts. Of these the left duct is the longer. The right and left ducts do not accurately represent the drainage vessels for the right and left lobes respectively. The length of the hepatic duct is about 3 cm., and its average diameter is 5-6 mm. It lies in the ventral boundary of the foramen of Winslow and gradually increases in calibre as it passes from its commencement to its termination.

The common bile duct is formed by the junction of the cystic and hepatic ducts behind the first part of the duodenum. It passes dorsal to this portion of the bowel, and then lies between the second part of the duodenum and the head of the pancreas. Lastly it passes through the medial and dorsal portion of the duodenal wall to open on Vater's tubercle about midway between the commencement and termination of the second part of the organ. It is embedded in the duodenal wall for about two cm. The duct is thus conveniently divided into duodenal (or retroduodenal), pancreatic and intramural portions. Its length is 6-7 cm. (58), and its calibre diminishes from its commencement to its termination. The duodenal part is 8 mm., the pancreatic part 5 mm., and the intramural part 3·5 mm. in diameter (248). The duodenal part of the common duct is closely related to

the inferior vena cava, the portal vein (101) and the gastro-duodenal trunk of the hepatic artery, whose branches are twined around the duct itself (275). The pancreatic part of the common bile duct is entirely surrounded by pancreatic tissue in 80 per cent. of cases. In 20 per cent. it is either partially surrounded or merely grooves the gland (8).

Vater's tubercle may present one or two openings according to whether the common bile duct and pancreatic duct join to form an ampulla or remain separate. They open separately in 22 per cent. of cases (8). If one opening only is present, it is never more than 3 mm. in diameter (58). No fluid can be forced into the ducts by distension of the duodenum, but fluid can easily be driven into the duodenum by distending the gall bladder (Cruveilhier).

Rost claims that if the gall bladder be removed in persons whose Vater's ampulla is surrounded by a long sphincteric muscle, this sphincter acts so as to occasion a dilatation of the bile passages in a few weeks, thus producing an adventitious gall bladder, but he states that if only a short sphincter exists, no such action occurs (295).

The diminishing calibre of the common duct as it passes to its termination explains the comparative frequency of stones in the terminal portion of the duct. Mayo Robson states that stones in the bile ducts occurred in 39·4 per cent. of his operations for gall stones. Stone in the hepatic duct is almost invariably secondary to stone in the common duct. Pigment calculi alone occur as a primary condition in the hepatic duct (338).

The variations in the bile system were recently reviewed by Milne (239), who gives a good table.

Lewis and Thyng have pointed out that diverticula are to be found throughout the bile system in embryonic life. They may give rise to glandular tissue (hepatic and pancreatic), they may degenerate and disappear, they may form detached cysts, or may possibly give rise to permanent diverticula of the gall bladder (204).

Fenger has shown that the portions of the bile ducts which are most convenient for choledochotomy because of their freedom from surrounding vessels are the upper two-thirds of the cystic duct and the middle portion of the common duct (101). For stone in the ampulla of Vater it is better to operate by the transduodenal route than by mobilisation of the duodenum and opening of the pancreatic portion of the duct. In the latter operation one has to remember the likelihood of adhesions to surrounding tissues, the proximity of the inferior vena cava and the possibility of a fistula following the operation.

A nodule of malignant disease in the head of the pancreas may closely simulate a stone in the pancreatic portion of the common duct.

An enlarged lymphatic node in the right free margin of the lesser omentum may resemble a stone in the terminal part of the cystic duct or in the commencement of the common duct.

The gall bladder is supplied by the cystic branch of the hepatic artery and by the deep or lesser cystic arteries. The latter vessels pass from the substance of the liver through the intervening areolar tissue to the upper aspect of the gall bladder.

The cystic artery is given off by the hepatic trunk near the hilum of the liver. It passes above and to the left of the cystic duct to the neighbourhood of the neck of

the gall bladder, where it divides into two branches. These run along the left and right sides of the gall bladder as far as the fundus. On the other hand the cystic artery may arise from the right branch of the hepatic trunk, and its parent artery may come from the superior mesenteric vessel (a point to be remembered in tying it for hæmorrhage), or it may arise from the gastro-duodenal artery (175).

Brewer states that a branch of the hepatic artery lies to the right of the cystic duct in 30 per cent. of cases (40). In cholecystectomy the cystic vessels may be found and ligatured above and to the left of the cystic duct or neck of the gall bladder. The free arterial supply of blood to the gall bladder is probably the reason for the comparative rarity of gangrene of this organ in contradistinction to the frequency of gangrene in inflammation of the appendix.

The cystic duct receives its vascular supply from the cystic artery. The hepatic ducts and the upper part of the common duct are supplied directly from the hepatic trunk. The lower part of the common duct derives its blood from the superior (right) pancreatico-duodenal artery.

Fenger has pointed out that the portal vein is closely related to the common duct. It lies to the lateral side of the upper third of the duct and may even overlap it in front (101).

The lymphatics from the bile passages run to the hilum of the liver, where they join the efferent vessels of that organ. The lymphatics from the lower part of the common duct form an exception to this generalisation. They pass to join the lymphatic plexus on the duodenum. The lymphatic nodes along the hepatic

pedicle form a continuous series from the hilum of the liver to the lesser curvature of the stomach, and are frequently involved in carcinoma of the pyloric region.

The peritoneal drainage area of the bile system is the right kidney pouch (see p. 22).

The nerves of the bile passages come from the eighth and ninth dorsal segments of the spinal cord (133). They reach their destination by way of the solar plexus. Referred pain from the bile passages is frequently found, in consequence, in the right infrascapular region. The presence of this pain constitutes Boas' sign. Direct pain is due to local peritonitis over the fundus of the gall bladder. This is most apparent on pressure over Mayo Robson's spot, a point at the junction of the middle and inner thirds of a line joining the ninth right costal extremity with the umbilicus (287). Murphy's sign is also dependent for its occurrence on local peritonitis, and is elicited by deep pressure under the right costal margin. There is some experimental evidence in favour of the derivation from the vagus of some of the nerves to the gall bladder (73).

III. The Pancreas.

The pancreas is deeply situated in the abdomen. Its head is surrounded by the duodenum, while its body and tail lie dorsal to the stomach. It is not surrounded by a "capsule," but when irritated, a fibrous sheath is formed around it from the peritoneum and subperitoneal cellular tissue (230). On the abdominal wall the general situation of the head may be outlined by mapping out the duodenum (see p. 115, and fig. 19). The body and tail lie along Addison's plane, and the latter reaches the left hypochondrium and can be approached through an

incision in the left loin. Crane has shown that the general shape of the head of the pancreas may be outlined by radiographic examination of the duodenum if it be carried out in a modified manner.

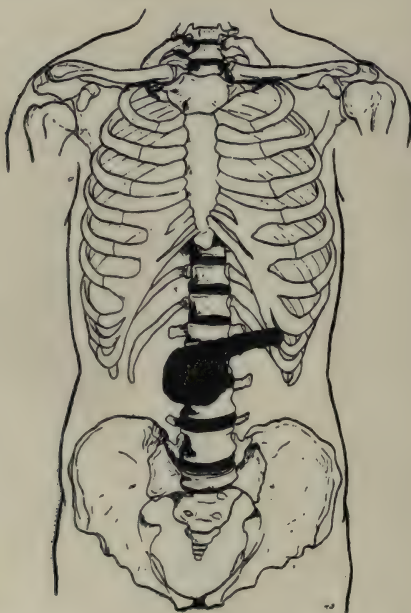


Fig. 32. Surface topography of the pancreas as observed in the cadaver.

Note that by taking the necessary precautions for the radiography of the duodenum, the outline of this portion of the gut indicates in a general manner the site of the head of the pancreas. Compare this with the outline indicated for the pancreas by the position of the duodenum in figs. 16, 19, 21, 31.

Cole has been able to demonstrate the shadow of bismuth in the duct of Wirsung (75). The main duct (of Wirsung) of the pancreas opens on Vater's tubercle

with the common bile duct. In 22 per cent. of cases they open separately into the duodenum. In 78 per cent. they open together into Vater's ampulla (8). In the latter instances, obstruction of the duodenal opening of Vater's ampulla may cause regurgitation of bile along the pancreatic duct and set up pancreatitis. Pancreatic calculi contain 50 per cent. of calcium carbonate, and are therefore visible in radiographic examinations (288).

The accessory pancreatic duct (of Santorini) is of the same calibre as the main duct until the seventh to the ninth month of fœtal life, when its relative size diminishes. It is patent and joins the main duct in the substance of the gland in about 80 per cent. of cases (8). Its opening into the duodenum is on the medial wall at the apex of a small papilla two or three cm. above the opening of the common bile duct. Its patency and communication with the main duct provide an outlet for pancreatic juice in certain cases where the main duct is obstructed.

Hess has pointed out that there are two clinical types of congenital obliteration of the common bile and pancreatic ducts. In one type, although both are obliterated, the accessory pancreatic duct remains patent and functional. In the other type the accessory duct is also absent (149).

The pancreas lies entirely dorsal to the peritoneum, and hence pus will travel from the gland upward into the subphrenic region or downward into the left iliac fossa (288).

In operations on the gland particular care must be taken of the middle colic artery which courses upward in front of the head (288). Injury to this vessel results in gangrene of the transverse colon, because of the lack

of anastomosis between vessels on the wall of the bowel itself.

The blood supply of the pancreas comes from the superior and inferior pancreatico-duodenal arteries and from branches of the splenic artery as it runs along the cephalic border of the gland. Its blood supply is then for the most part the same as that of the duodenum.

The lymphatic vessels do not fall into one or two groups, but follow the vascular supply. They emerge at various points along the course of the gland and pass through the retroperitoneal cellular tissue to join the lymphatic nodes around the pancreas itself and the juxta-aortic nodes, as do those of the duodenum (272). The importance of the widespread lymphatic drainage in infections of the gland is emphasised by Deaver and Pfeiffer (79).

The nerves come from the solar plexus. Disease of the gland results in pain which is present *between* the scapulæ rather than below the right scapula as in the case of the gall bladder (288). In acute inflammation of the gland local tenderness due to peritonitis may occur above and to the right of the umbilicus (288).

Acute lesions of the pancreas are accompanied by much shock and cyanosis, which are said to result from stimulation of sympathetic nerves; the pancreas, from its position in the abdomen, being intimately associated with the solar plexus.

Cysts of the pancreas may be palpated above or below the stomach. They are especially difficult to diagnose from mesenteric or omental cysts, and from pseudo-cysts of the pancreas. The last-named are in reality effusions into the lesser sac of the peritoneum (206).

Sometimes a ring-shaped portion of the pancreas

encircles the duodenum, most frequently the second or descending part (6), and may cause constriction of the gut (233).

An accessory pancreas, usually in the form of a mere nodule, is sometimes found in the wall of the stomach or the intestine, and the former variety may account for some cases of congenital hour-glass stomach (see p. 68) (202). Carwardine and Short state that such a nodule is usually situated in the wall of the stomach near the pylorus or the greater or lesser curvatures, in the wall of the duodenum but detached from the true pancreas, in the first eight inches of the jejunum, which is the commonest site, or in the lower jejunum or ileum even near the ileo-cæcal valve. Very occasionally it has been found in the abdominal wall at the umbilicus. It is subject to the same diseases as is the true pancreas (55).

Note on the Ileo-Pyloric Reflex.

Since this book went to Press, I have received the second edition of Dr. A. E. Barclay's monograph ("The Alimentary Tract," London and Manchester, 1915), and therefore take this opportunity of drawing attention to what Dr. Barclay has termed the ileo-pyloric reflex.

In cases of duodenal irritation the stomach commences to empty rapidly, but in some instances this continues only a short time (half to three-quarters of an hour), and then ceases, so that the stomach presents radiographically a retention of contents similar to that observed in pyloric obstruction. In such cases the cessation of the passage of food through the pylorus and of general activity in the stomach coincides with the appearance of heavy shadows in the terminal portion of the ileum. There is no doubt, therefore, that in this comparatively short time contents have passed along the whole length of the small intestine. As pressure, externally applied, will no longer cause food to pass through the pylorus, Barclay suggests that reflex closure of the stomach exit has taken place in consequence of a stimulus originated from the mucosa of the distal portion of the ileum, and that this phenomenon affords yet another instance of the intra-alimentary system of reflexes.

If, after a time, more food is given, the ileo-cæcal sphincter relaxes and permits the passage of ileal contents into the large bowel. This is simply a specific instance of the general truth that the giving or even the smelling of food induces emptying of the ileum into the colon. The spasmodic closure of the pylorus, however, reflexly originated from the ileum, would seem to be a protective against the excessive overloading of the small bowel with chyme which has not yet fully undergone the changes natural to its exposure to the jejunal-ileal mucosa.

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